A GEOLOGICAL ESSAY

ON THE

IMPERFECT EVIDENCE

IN SUPPORT OF A

THEORY OF THE EARTH,

DEDUCIBLE EITHER FROM

ITS GENERAL STRUCTURE

OR FROM

THE CHANGES PRODUCED ONITS SURFACE BY THE OPERATION OF EXISTING CAUSES.

BY

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TO

GEORGE BELLAS GREENOUGH, Esq.

F. R. S. &c.

VICE-PRESIDENT OF THE GEOLOGICAL SOCIETY.

MY DEAR SIR,

IF my own sentiments of respect for you had alone prompted me to solicit the honour of inscribing this dedication with your name, I should perhaps have hesitated in making the request; but, conscious that I participate in those sentiments with many in this University, whose friendship you value, and whose kindred labours in Geology you have both encouraged and approved, I felt that in making this declaration I might offer you a tribute not unworthy your acceptance.

With many thanks, then, for the permission you have given me to place this dedica-

tion in front of the present Essay; and with every hope that your connection with Oxford may become stronger each succeeding year, I remain,

My dear Sir,

Your most obliged

and sincere Friend,

J. KIDD.

Oxford, Feb. 27, 1815.

PREFACE.

THE general object and the arrangement of the following Essay are so fully shewn by the Title Page and the Table of Contents, that I need not say any thing further in explanation of those points. With respect to the object itself, or the plan which I have adopted in its pursuit, I am so far from wishing to lay any claim to exclusive originality, that I should be gratified by the knowledge that others had been contemplating the same subject with the same views: and it appears from M. Cuvier's late Essay on the Theory of the Earth, a translation of which was published in 1813, that he has in some measure anticipated the attention of the public with respect to that part of the present volume which treats of the operation of existing causes. But I think it due to myself to state, that my own plan was arranged long before I knew that M. Cuvier had written the Essay in question: and with respect to any opinions maintained by M. De Luc in his Letters to the Queen, in which work he examines at considerable length the action of existing causes on the earth's surface, I have it in my power to say with truth, that I not only had not read that work till within the

last few months, but was not at all aware that it contained the opinions in question.

If any of my readers should think that I have made too frequent use of the works of other Authors, I beg leave to remind them, that the very nature of the present publication required the numerous extracts and references which I have made. In the mean time I can assure them, that in extracting from the writings of others I have neither had it in view to increase the bulk of this volume, or to save my own exertions. The arrangement of those extracts indeed has constituted the chief part of my labour, and occupied the greatest share of my attention: for a single illustration has sometimes been composed partly by compressing the original account from whence it has been drawn; partly by combining from different parts of the same author, and sometimes even from different authors, the particulars of which the illustration consists. As on such occasions it would have been ostentatious to give all the references, I hope that, if in comparing my statements with the original there should not always be a literal agreement, the reader will not hastily accuse me of negligence.

Of the propriety of entering into the discussion of the subject of the first chapter, which treats of the connection between Geological Speculations and the Mosaic history of the Creation and Deluge, there will perhaps be a difference of opinion: and those even who approve of its insertion, may

yet think it would have been better placed at the end of the volume. I trust however that, in my manner of treating the question there discussed, I have preserved that temper which I have ventured to recommend to others. It was not my intention to have mentioned the name of the author from whom I have made such copious extracts in the seventh and eighth pages; and if I now state that they are contained in a work of M. Albert Fortis on the Geology of Italy[a], it is at the suggestion of a friend whose judgment I respect: nor should I have introduced the extracts themselves for the mere purpose of exposing their eccentricity, had I not had a different and a better end in view.

I beg leave to apologize for the numerous errors in the notes of reference by stating, that it was not in my power to correct them till within three days of the printing of the last sheet. I have since examined the original passages, (with the exception of those in Ramond and Ferrara, whose treatises I have not now in my possession,) and have inserted in the list of errata at the end of the volume all the material corrections. In a few instances however, which are noticed in that list as incorrect references, I was unable to discover the source of error.

Variations from the true reference which do not exceed the limits of two pages I have omitted to particularize: because, as in consulting any reference the reader would be naturally led to examine more

[a] Tom. i. p. 204, 209, 211.

than the passage immediately referred to, he will, after what I have said, be enabled to obviate the inconvenience of such errors with nearly as little trouble as he could have done by means of a corrected statement. I do not mean, however, by omitting the actual correction to hide the number of the errors in question; nor need I be ashamed to say, considering their trivial nature and my own want of leisure during the printing of this Volume, that they amount to as many as nineteen or twenty.

In offering this Essay to the public, I take a final leave of the pursuit of Mineralogy; in doing which, I am naturally prompted to express my obligations to those who materially assisted me in that pursuit, and to whose exertions during the last ten years it is principally owing, that the Museum of this University possesses its present extensive and most valuable geological collection.

To the Rev. Philip Serle of Trinity College, the Rev. William Buckland of Corpus Christi College, (my successor in the professorship of mineralogy,) to Henry Drummond, Esq. and the Rev. John and the Rev. William Conybeare of Christ Church, (to all of whom I am united by the firmest ties of friendship,) I particularly express my obligations: for without their assistance I could not, with satisfaction to myself, have continued to deliver those Lectures, which I have now resigned to one, from whom I should have thought it an injustice to the University longer to withhold them.

Books referred to in the following Essay, arranged in the order of their reference.

MEMOIRES pour servir à l'Histoire Naturelle &c. de l'Italie, &c. par Albert Fortis, &c. &c. A Paris, 1802. 2 tomes, 8vo.

Butler's Analogy of Religion, Natural and Revealed. 8vo. Oxford, 1807.

Mémoire sur les Basaltes de la Saxe, &c. par J. F. Daubuisson. A Paris, 1803. 8vo.

Illustrations of the Huttonian Theory of the Earth, by John Playfair, F. R. S. Edin. and Professor of Mathematics in the University of Edinburgh. Edin. 1802. 8vo.

Voyages dans les Alpes, &c. par Horace-Bénedict de Saussure, tom. viii. 8vo. A Genève, 1786. et à Neuchatel, 1796.

Ramond, Voyage au Mont Perdu, et dans la Partie adjacente des Hautes Pyrénées. 8vo. Paris, 1801.

Essai de Géologie, par B. Faujas-St.-Fond. A Paris, 1809. 12 tomes, 8vo.

Guillelmi Leibnitii, &c. Opera omnia. Genev. 1768. vol. vi. 4to.

Annales du Muséum National d'Histoire Naturelle. A Paris, 1802, &c. 4to.

The Natural History of the Mineral Kingdom, &c. by John Williams, F. S. S. A. 2 vol. 8vo. Edin. 1810.

General View of the Agriculture and Minerals of Derbyshire, by John Farey, Sen. Lond. 1811. 2 vol. 8vo.

Geological Travels, by J. A. De Luc, F. R. S. Lond. 1810, 1811. 3 vol. 8vo. Translated from the French MS.

Geological Travels, &c. by J. A. De Luc, F. R. S. Lond. 1813. 2 vol. 8vo. Translated from the French MS.

N. B. These two works are referred to as consisting of 5 successive volumes.

De Luc, Lettres, &c. sur l'Histoire de la Terre. tomes v. 8vo. à la Haye et à Paris, 1779.

Essai politique sur le Royaume de la Nouvelle-Espagne. par Al. De Humboldt. Paris, 1811. tomes v. 8vo.

System of Mineralogy, by Robert Jameson, Regius Professor of Natural History in the University of Edinburgh, &c. 3 vol. 8vo. Edin. 1804.

Ferrara (Abbate Francesco) Storia generale dell' Etna. 8vo. Catania, 1793.

Notice sur l'Histoire Géognostique du Cotentin. Extrait du Journal des Mines, No. 206. Février, 1814.

Voyages de P. S. Pallas. 5 tom. in 4to. à Paris, 1788—1793.

Travels in China; by John Barrow, Esq. Lond. 1804. 4to.

A Geographical Memoir of the Persian Empire, by John Macdonald Kinneir. Lond. 1813. 4to.

The Voyage of Nearchus, by William Vincent, D. D. Lond. 1797. 4to.

Memoir of a Map of Hindostan, &c. by James Rennell. Lond. 1788. 4to.

Travels in Hungary, by Robert Townson, LL. D. &c. 4to. Lond. 1797.

An Account of an Embassy to the Kingdom of Ava, by Michael Symes, Esq. Lond. 1800. 4to.

A Comparative View of the Huttonian and Neptunian Systems of Geology. Edinb. 1802. 8vo.

Essai sur la Géographie Mineralogique des Environs

de Paris. par M. M. G. Cuvier, et Alex. Brongniart. 4to. pp. 278.

A Voyage to Abyssinia, &c. by Henry Salt, Esq. F. R. S. &c. Lond. 1814. 4to.

The Periplus of the Erythrean Sea, Part 1. Lond. 1800. 4to. Part 2. Lond. 1805. 4to. by William Vincent, D. D.

Mémoire sur les Iles Ponces &c. par Déodat de Dolomieu. A Paris, 1788. 8vo.

Voyage aux Iles de Lipari, par Déodat de Dolomieu. A Paris, 1783. 8vo.

An Account of an Embassy to the Court of the Teshoo Lama, in Tibet; by Captain Samuel Turner. Lond. 1800. 4to.

Observations faites dans un Voyage entrepris dans les Gouvernements Méridionaux de l'Empire de Russie. Par P. S. Pallas. Traduit de l'Allemand. 2 tomes. 4to. Leipzig, 1799—1801.

Travels in Upper and Lower Egypt, &c. by Vivant Denon, translated by Arthur Aikin. Lond. 1803. 4to.

A Voyage to Cochinchina, by John Barrow, Esq. Lond. 1806. 4to.

A Voyage to Terra Australis in the Years 1801, 1802, and 1803. in H. M. S. Investigator, &c. by Matthew Flinders, Commander. 2 vol. 4to. Lond. 1814.

Observations made during a Voyage round the World; by John Reinold Forster, LL. D. &c. Lond. 1778. 4to.

A Voyage towards the South Pole, &c. in 1772, &c. by James Cook. 2 vol. 4to. Lond. 1777.

The Journal of Frederick Horneman's Travels in Africa. Lond. 1802. 4to.

Essay on the Theory of the Earth, translated from the

French of M. Cuvier, &c. by Robert Kerr, &c. Edin. 1813. 8vo.

Travels in the Island of Iceland during the Summer of 1810, by Sir G. Mackenzie, Bart. 4to. Edin. 1811.

The First Report of the Commissioners appointed to enquire into the Nature and Extent of the several Bogs in Ireland, and the Practicability of draining and cultivating them. Ordered by the House of Commons to be printed. June 20, 1810.

The Second Report, &c. April 1, 1811.

The Posthumous Works of Robert Hooke, M. D. &c. Lond. 1705. fol.

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CHAPTER I.

On the nature of the connection between Geological speculations and the Mosaic history of the Creation and Deluge.

SINCE the Book of Genesis gives an account, and in some measure a detailed account, of the creation of the earth; and records, besides, the catastrophe of a universal deluge which subsequently overwhelmed it; there is an obvious connection between Geological speculations and the Mosaic history of the World. Whether the two are ever likely to be reconciled by means of unassisted reason I do not here inquire: but it seems very probable that from a want of perception of, or from inattention to, the nature of that connection on one side, and from an indiscreet zeal on the other, much unnecessary asperity has attended the discussion of questions connected with such speculations.

As all may possibly be lost by a renunciation of Revealed Religion, while no equivalent is offered but the establishment of some physical proposition, what advocate for moral consistency will deny that the above connection should seriously be kept in mind; and that such propositions, as may possibly admit of an interpretation subversive of the authority of the Scriptures, should be so guarded

as to expose the fallacy of the apparent opposition; or should at least be advanced as simply deduced from the phenomena, without any intention of weakening the authority of received opinions in a matter of so great moment? But then, on the other hand, since even the firmest advocates for Revealed Religion may in the ardour of philosophical pursuit overlook the consequences of a particular conclusion, and may thus by implication commit the integrity of their own faith; it is equally undeniable, in a philosophical as well as a religious point of view, that we ought in all possible cases to put a candid construction upon the intentions of those, who may have advanced any proposition that is apparently, or even really, in opposition to Revelation: guarding others, indeed, against the tendency of such propositions; but avoiding those charges, which, as an elegant writer has mildly observed in defence of his friend, "have a less direct tendency to overthrow the system than to hurt the person of an adversary, and to wound, perhaps incurably, his mind, his reputation, or his peace."

Those who are acquainted with the literary history of Geology will perceive that the foregoing observations are applicable to some particular passages in the philosophical writings of the late Dr. Hutton and Mr. Kirwan, to the circumstances of which I am now led to advert, as connected with the view of the present chapter; neither however as an advocate of Dr. Hutton, nor as an adversary of Mr. Kirwan.

One of the fundamental propositions of Dr.

Hutton's theory is this, that the materials are now preparing for the formation of future continents, by the gradual waste of those which we at present inhabit; that those materials, which have been abraded or detached by the action of the atmosphere and other natural causes, are carried down by rivers and accumulated at the bottom of the ocean; from whence, having been first consolidated or even melted by subterranean heat, they are hereafter to be elevated by a force acting from beneath.

He argues moreover, and to many renders it extremely probable, that the strata of our present continents were formerly produced by a similar process; resting the evidence of his hypothesis principally on the existence of various rocks usually called Sandstones and Conglomerates, which in his opinion and that of many others must have been formed from the fragments or comminuted parts of pre-existing rocks: and as some of the integrant parts of these Conglomerates appear by the same evidence to have belonged to rocks which themselves had been previously formed from the remains of others still more ancient, he deduces the probability that this process has been carried on through many successive periods. And as it is also a part of his theory that even those rocks, which bear no present marks of mechanical origin, have only lost that character in consequence of subsequent fusion; hence he argues that in the strata themselves there is no vestige of a beginning, nor by analogy is there any sign of an end.

It was this part of the theory which induced Mr. Kirwan to accuse Dr. Hutton of advancing atheistical propositions, in which he was certainly not justified, either in candour or in truth: not in candour, because Dr. Hutton repeatedly insists on the manifestation of "Divine wisdom in the presence and efficacy of design and intelligence perceptible in the construction of the earth;" and to the same end frequently points out the operation of final causes: not in truth, because the proposition itself neither precludes the supposition of original creation, nor of final annihilation. Let us for instance borrow an argument from a parallel case in a much higher, the highest branch indeed of Physics. By astronomical calculation then, deduced from the regularity in the motions of the heavenly bodies, we are enabled to determine the relative positions of these bodies at any moment prior or subsequent to the present; and with a degree of probability so high, reasoning that is from experience, as almost to amount to certainty: and as there is a provision by which the periodical variation in the motions can never exceed a given point, it is a self-evident proposition, that in these motions themselves we neither see the vestige of a beginning, nor the sign of an end. But it does not follow from hence that they never had a beginning, nor will ever have an end: on the contrary, as there is the strongest presumption that such harmony must have been the effect of the operation of an intelligent Creator, who may consistently be supposed capable of altering or destroying, as he was capable of producing, his own works, the

very opposite conclusion is strictly deducible. But if the spirit of those who hastily charge with impiety opinions advanced in discussions merely philosophical be worthy of censure, much more so is the spirit of those who dare to treat with asperity and ridicule, or even with levity, those prejudices, as they are pleased to call them, which, if not drawn by each individual from an actual examination of his religion, may be necessarily connected with a belief in it: to which prejudices may in part be applied what Butler in his Analogy has said of the Bible—"A Book of this nature," he observes, "received as a revelation by a great part of the civilized world, demands, as if by a voice from heaven, to have its claims most seriously examined into; and that, before such examination, to treat it with any kind of scoffing and ridicule, is an offence against natural piety."

Neither are all prejudices unphilosophical; nor do they answer to the definition of the term as commonly used: for, supposing the moral evidence of the *general* credibility of Scripture for instance to be sufficiently strong to command the assent of any individual; and that some *particular* fact, as a universal deluge, were *necessarily* involved in that credibility: then, considering the fallacies we are liable to in the interpretation of natural appearances, although the evidence from this source were ever so strong against such a fact; were the traces of fire for instance present every where, and the trace of water no where, that assent could not consistently be shaken.

It would occupy too much time were I to pro-

duce all the offensive passages of the publication which led to the foregoing reflections; nor is it my aim to attack the characters of authors, by whatever motives they may have been influenced in their writings. I shall be satisfied with describing in general terms the reprehensible spirit to which I have above alluded. If then a writer studiously seizes occasions of casting an odium on the members of the clerical profession, or of treating them with contempt; and if he speaks in terms of hostility and ridicule, or even with dissatisfaction and impatience, of opinions sanctioned by the Religion of his country; such a writer, it may be justly asserted, acts in a manner offensive to moral decency; especially when he is found offering the language of almost divine adoration at the shrine of human institutions.

Nor will it perhaps be altogether without its use to mention one or two original speculations of an author, who throughout the work in question appears most unwilling to be trammelled by any thing like established authority. "I know," says the writer in question, "that some persons are very much offended at those who assert the high antiquity of our globe, &c: nevertheless I shall venture to mention my conjectures respecting the epoch of our origin, and the possibility of our derivation from the perfected state of some class of beings which partook of the human form.

"Perhaps it is an extraordinary supposition, yet by no means contrary to sound sense, and very far from unnatural, that the human species being

susceptible like all others of infinite deterioration and perfectibility, as well in physical as in moral constitution, has already passed and will still pass through innumerable links, the epochs, causes, and modifications of which could not be recorded in any history, nor individually foreseen by any philosopher.

" Among the modifications which animals now inhabiting the land may have hitherto undergone, I can easily suppose one which would have enabled them to live and multiply their species under water. Did then these animals originate in an aquatic or terrestrial state? Have they undergone alternations of these two modes of existence? Were they metamorphosed from the form of their prototypes at once, or by degrees? These are questions indeed that cannot be answered: it is however a matter of fact, that the traces of an internal structure, which would enable them to live independently of the process of respiration, still exist in warm-blooded animals; for during the first months of their existence, a period which they pass in a constant state of immersion, their blood passes from one ventricle of the heart to the other: and we know that the foramen ovale has been found open in the case of adults, who had no idea during their life-time of possessing this rare privilege."

In another part of the work in question the same writer says, " If we may form a judgment from what is observable on land, of the variety in the forms and in the economy of the inhabitants of the ocean; there is not perhaps a

part which has not its appropriate species of animals or plants exclusively attached to it: so that as we have birds which are unable to elevate themselves from the ground, as Cassowaries, Ostriches, Penguins, &c. there is no extravagance in supposing there may be many species of fish, hitherto undiscovered, whose organs are not calculated to enable them to rise towards the surface of the water. Why should not the ocean possess animals, analogous in a greater or less degree to the Phocæ, which living gregariously at the bottom of its deepest parts enjoy a much greater share of tranquillity than those ill-fated species whose affections and whose security are annually disturbed by the savage Kamschatkadale and the rapacious European? And who can say that there are not in the immense plains, and innumerable vallies, which the waters of the ocean conceal from our eyes, and screen from our investigation, some race of animals of still higher intelligence than ourselves; more capable of complicated ideas, and consequently more susceptible of social forms, though restrained by physical impossibilities from rising from the bottom of the ocean, as we are from elevating ourselves into the superior regions of the air?"

Again, speaking of certain tribes who feed principally on fish, he says, "Those savage Ichthyophagi have doubtless organs and secretions different from ours. If they originally inhabited the ocean, it must be confessed that they still retain in a great measure their former nature; and if they should hereafter be com-

pelled to quit the land and become inhabitants of the ocean, it is evident that they would be much less incommoded than we should by such a change, which to them would be but partial. For the rest, nature would come to their assistance; that kind mother towards all those who do not themselves mar her intentions."

The reader perhaps will agree with me, that, were it not for that concluding apostrophe, it would have been unfair to quote the preceding part of the paragraph in any other view than as an instance of intended and happy irony. The author does indeed add, " this is however indulging too much in dreams; and perhaps the patience of the reader is already exhausted."

But, to return to the author himself, it may be said, and probably with justice, that such reflections and language as he has made use of were provoked by the bigotry and hostility of others; though this does not lessen the offence in a general point of view: or it may be said, that many otherwise well-disposed persons are in the habit of raising a phantom of their own imagination for the mere purpose of combating it; and that contempt or ridicule of the scruples of individuals is not dictated by any feeling of hostility towards Religion; between which and Philosophy there is no natural variance.

That there is not necessarily and always a natural variance between Philosophy and Religion I allow; but that there is not occasionally such a variance is a point, which may at least be said to be disputable; and on which, with all becoming

diffidence, and with entire respect towards those whose more immediate province it is to discuss such questions, I beg leave briefly to express my opinion.

Few observations are more common, where opportunities of making them occur, than that those persons who are much engaged in the contemplation of natural phenomena are apt to be sceptical with respect to matters of religious belief; sometimes even with respect to the existence of the Deity: and Lord Bacon, if I remember rightly, argues in the case of such persons, that probably by the assiduous contemplation of second causes they insensibly lose sight of the great First Cause. But, if I may be forgiven for questioning the interpretation of so great a master, it appears to me more probable that in those persons who have a natural disposition to investigate physical truths, there is also a natural disposition to reject, or at least to question, all evidence that does not come home to the senses: and this constitutional connection is, perhaps, though unconsciously, pointed out in those lines of Lucretius,

> Et quoniam docui cunctarum exordia rerum
> Qualia sint, &c.

and still more plainly in Virgil's beautiful paraphrase of that passage—

> Felix qui potuit rerum cognoscere causas;
> Atque metus omnes, et inexorabile fatum
> Subjecit pedibus, strepitumque Acherontis avari.

Since moreover it is a matter of fact, that among the early philosophers the contemplation of the

apparent inconsistencies of nature led towards, and were among the strongest incentives to Atheism; it is hence at least probable that similar difficulties may operate in a similar manner at the present day with respect to Revelation: and who shall say, since many of these apparent inconsistencies have been decisively shewn to be reconcileable with the general scheme of Providence, and in other instances may be considered rather beyond than contrary to reason; whether, as one collateral final cause of their existence, they may not serve as a touchstone, to use the expression of Grotius, "ad quem sanabilia ingenia explorarentur?"

Such at least is Butler's opinion, again and again expressed, who says, "The evidence of Religion not appearing obvious, may constitute one particular part of some men's trial in the religious sense; as it gives scope for a virtuous exercise or vicious neglect of their understanding in examining or not examining into that evidence: for there seems no possible reason to be given why we may not be in a state of moral probation with regard to the exercise of our understanding upon the subject of Religion, as we are with regard to our behaviour in common affairs[a]."

In another part he says, "There does not appear any absurdity in supposing that the speculative difficulties in which the evidence of Religion is involved may make even the principal part of some persons' trial[b]."

And again, "If there be any persons who never

[a] Analogy, p. 307. [b] P. 316.

set themselves heartily and in earnest to be informed in Religion; if any accustom themselves to consider this subject in the way of mirth and sport; if there are any who secretly wish it may not prove true; and are less attentive to evidence than to difficulties, and more to objections than to what is said in answer to them: these persons will scarce be thought in a likely way of seeing the evidence of Religion, though it were most certainly true and capable of being ever so fully proved[c]."

From the foregoing and from numerous other passages, it is clear Butler thought it not only possible, but probable, that with respect to those temptations, in the combating of which both moral and religious virtue are concerned, there may be some minds whose trial consists in the difficulties accompanying the acceptance of that imperfect evidence afforded by Religion, natural or revealed. And I would ask whether that probability is not increased by the observation, that many, perhaps most, of those who are sceptical on the subject of Revelation, are by nature endued with that calmness of physical constitution which removes them from, or at least renders them less liable to, the temptations of the more violent passions: since both from natural and Revealed Religion we must all be supposed liable to some prevailing temptation.

To return to the more immediate subject of the present chapter, my own opinion of the nature of the connection between Geological speculations and

[c] Analogy, p. 319.

the Mosaic history of the Creation is this, that, arguing from the brief account contained in the Book of Genesis, and from the analogy of the rude state of knowledge at that time in all other particulars, it is highly probable that the main point intended to be inforced by the inspired writer was the belief that God is the Creator of the world, and of every thing contained in it: and that from such slight materials to attempt to explain the detail of Geological phenomena, or to limit the progress of knowledge by the literal interpretation of so brief and mysterious a history, are equally unreasonable.

That the Deity created all things, and that the human race has not existed for a longer period than that assigned by the chronology of Scripture, are points which no one has, I believe, yet denied; and which all have agreed in, whose authority is of any weight: and since the periods called days in the Mosaic history of Creation appear from the very terms of the history to have differed in their nature from what we now call by the same name, it is clearly impossible on that supposition to define the measure by which they are to be estimated; and it is, or to me at least seems immaterial to our belief in the main point, whether they severally answer to only one, or to ten million revolutions of our globe.

With respect to the connection between Geological speculations and the Mosaic history of the Deluge, the argument seems to be of the same nature as in the preceding instance: the facts, I think, both of the universality of the Deluge and

of the destruction of all mankind with the exception of one family, must be admitted by all who admit the general credibility of Scripture: but it evidently was an operation not brought about by the ordinary course of nature; or, in other words, a miracle; and probably therefore for ever inexplicable in its detail by unassisted reason.

With respect to the question how far a Theory of the Earth is likely to affect our belief in Scripture, I would simply observe, that, from the endless discordance in the opinions of philosophers on this point, from the manifest inadequacy of the data we are at present in possession of, and from the physical impossibilities which must for ever be a bar to more than a superficial knowledge of the Earth's structure, it is preposterous to suppose that that high degree of moral evidence on which the credibility of Scripture rests can with any justice be weakened by our interpretation of phenomena, the connection of which among themselves even we certainly are at present, and probably ever shall be, incapable of explaining.

But I shall take the liberty of adding, what naturally follows from the foregoing observations, that it seems equally preposterous for any one to rest the credibility of Scripture on his own interpretation of Geological phenomena; because many of these phenomena being of a dubious character, and some at present totally inexplicable, it is very probable that in the progress of the science his arguments might be turned against himself; and he could not deny the force of the weapons he had himself chosen.

In the mean time I am far from refusing to acknowledge the utility of theory in general, since it both regulates and assists our apprehension of phenomena; besides which, his faculties and feelings must be dull indeed, who views, without attempting to combine, the facts which are continually presenting themselves to his observation.

Requesting then the reader to receive any speculation advanced in the present volume merely as deduced from the observation of facts, and with the view of rendering myself more intelligible, without any design of defending or opposing the opinion of others, I proceed to the main object of my present undertaking; which is to examine how far we are likely either from internal evidence, or from any analogy in the operation of existing causes, to frame a consistent and probable theory of the Earth.

CHAP. II.

On the general Structure of the Earth.

THE general Structure of the Earth, as far as we are acquainted with it from the operations of mining and other sources of information, consists of a succession of *beds* or *strata*; which, though often nearly parallel with the horizon, vary in their degree of inclination to every possible extent: so as frequently to be not only vertical, but even thrown back in an opposite direction; or contorted

in a great variety of ways; still however, in all these cases, preserving their general parallelism with one another.

But, although the first notion of *stratification* is usually acquired with great facility, it is not, I believe, till after repeated observation and reflection that any one feels conscious of possessing a comprehensive view of the subject.

We see indeed, and cannot but see at a glance, the regular succession of the strata as exhibited in the section of a quarry or in a natural cliff; but, from the usual irregularity of the surface, from the disturbances to which the strata collectively appear to have been subjected since their original deposition, and from many other causes, it requires a very experienced eye to trace the fact thus first observed over a large extent of country.

It is not however necessary to my present purpose to dwell either on the practical difficulties that occur in ascertaining the true position of the strata, or the mode of obviating these difficulties: nor need I now enter into any speculations on the probable cause of their apparent state of disorder. I shall only mention some circumstances of their history to which I may have occasion hereafter to refer, or the knowledge of which is likely to render my language more readily intelligible to those who have not been accustomed to Geological observations. There is one point however in their history, which it will be convenient to explain before I proceed any further; I mean that general resemblance so often observable in several contiguous strata.

And as a single slab of stone may easily be conceived to be made up of several laminæ, which though not all exactly of the same nature either with respect to dimensions, colour, consistence or substance, yet all contribute to the formation of the same stone; the individual character of which is recognized by their united assemblage: so, in the stratification of the earth, it is found that in a series of successively contiguous strata there is often that mutual and general resemblance, which argues a natural relation; whence such strata are justly classed together, and are technically called a *formation.*

The following facts will illustrate more particularly the nature of a formation.

The Scheibenberg, one of the basaltic summits of Saxony not far from Freybourg, consists of a series of strata, the lowest of which is gravel; the uppermost basalt: the intermediate strata, beginning from the lowermost, being sand, clay, and a rock called by the Germans Wacke.

It was in this mountain, according to Daubuisson, that Werner in 1787 first formed his hypothesis respecting the nature of basalt: and here having observed horizontal beds of gravel, sand, and clay, lying under a stratum of wacke; and that stratum of wacke lying under basalt; having also observed that they each insensibly passed into the nature of the stratum immediately superincumbent, namely, the gravel into the sand, the sand into the clay, &c.; he concluded that the several strata were of the same formation: and as basalt itself is found to pass into porphyry slate,

and porphyry slate into greenstone; those two rocks have also, on the authority of Werner, been admitted into the suite. Thus the bed between the basalt and the clay, in the instance of the Scheibenberg, partakes in its lower part of the slaty nature of the clay on which it is incumbent; and in its upper part, of the prismatic character of the basalt under which it lies[d]. It should here be added, that not only the insensible transition of similar and contiguous strata into each other justifies the classification of them under the same formation; but the alternation of even different strata. Thus Mr. Playfair observes, that if there is any principle in mineralogy, which may be considered as perfectly ascertained, it is that rocks similarly stratified and alternated with one another are of the same formation[e]. And Dr. Mac Culloch further argues, that different strata, if they alternate, must be collectively considered as of cotemporaneous formation[f].

To return to the subject of stratification in general:

If the tiles of a nearly flat roof were so placed, as to rise successively from under instead of falling over each other, their upper edges pointing towards or abutting against the ridge of the roof, such an arrangement would not inaptly represent the actual situation of the strata; which rise in many instances like so many inclined planes from under each other, and, after having advanced to a

[d] Daubuisson, p. 120, &c.
[e] Playf. Illustr. p. 170.
[f] Geol. Trans. vol. ii. 410.

certain extent, successively terminate at a higher level. In such a disposition it is clear that that stratum which rises from under all the rest must be considered, with respect to its whole extent, as the lowermost; although at the same time the level of its upper termination will be the highest point in the whole series. And thus it may be easily understood how, in a mountainous tract, the parts at the highest actual elevation may belong to the lowest of all the strata constituting the particular district: and again, how a river having its source on the lowermost of a series of strata may be constantly advancing upon strata farther and farther removed from the lowermost, till it terminate on the uppermost.

Suppose, for an instant, that the comparatively elevated granitic platform of Dartmoor were to subside, and that the slaty strata, which surround and every where rest upon it at a considerable angle of elevation, were to fall over the depressed mass so as to assume a horizontal position; the granite, which is now the highest, would thus become the lowest; and the slate, which even at its highest point of general elevation is at a lower level than the granite, would thus become the uppermost. And if in this supposed state of things the granite were elevated by some force acting from beneath, so as to break through the superincumbent slate, the exposed portion of its surface would, as it does now, form an elevated platform; round which the slaty strata would be arranged so as to incline inwards.

The order then of original formation of the se-

veral strata, supposing them, as is highly probable, to have been successively deposited, is marked by their relative position; for it is clear that, of any two, the stratum which is subjacent to or rises up from the under surface of the other must have been first deposited; and though, from the inclination of the strata in general, and from the peculiar manner of their arrangement, parts of the lowermost are ultimately brought to the surface as well as the uppermost, and at actually a higher level; yet still they must be considered as relatively the lowermost, because they rise from under all the rest: and, by a similar mode of reasoning, that stratum from under which all the rest successively emerge must be considered as the uppermost; although it should absolutely be at a lower level than the exposed portion of any of the others. The epithets then, highest and lowest, superior or inferior, &c. as applied to the strata, are always to be understood relatively to the supposed order of their original deposition; the terms, highest, and superior, being applicable to those last deposited; the terms, lowest, and inferior, to those first deposited.

In the foregoing instance of the roof of a house, the terminating edges of the tiles are comparatively mere lines; but it may easily be supposed that the natural strata are of any assignable thickness; and in this case their terminating edges will be often abrupt precipices, or inclined planes of considerable extent; and hence they are usually called the *escarpments* of the strata: and these necessarily look to the points towards which each stratum is

advancing. A line drawn on the surface of a stratum parallel to the escarpment of it is called the *line of bearing* of that stratum: and a line drawn at right angles to the former, which will be necessarily in the direction of the inclination of the stratum, is called technically its *dip*. The visible portion of a stratum, or that part included between its own escarpment and that of the adjacent stratum, is called the *outgoing*.

If I have been successful in the foregoing description, there will not be much difficulty in illustrating by means of it the stratification of England: but I must previously observe, that one portion of this island consists of strata, the succession and dimensions of which can be ascertained with tolerable precision; while in the remaining portion the strata are comparatively confused, and in many instances all traces of stratification are lost. If then a line be drawn from about Exmouth in Devonshire, to the north east extremity of Yorkshire, passing in its way through the vicinity of Cullumpton, Taunton, Bristol, Gloster, Tewksbury, Evesham, Warwick, Leicester, Newark, Doncaster, and York; in all that portion of England which lies to the N. W. of this line the stratification is comparatively confused: but in all that part to the S. E. a tolerably regular succession of the strata is observable; the several strata presenting their escarpments to the N. W., and dipping towards the S. E.; and having their general

line of bearing from the S. W. to the N. E.: so that if you proceed from any point of this line towards the S. E., you will cut transversely the several strata in succession. Or if, having advanced in this direction upon any stratum, you change your direction to the N. E. or S. W., you will continue to travel on the same stratum till you reach its termination either towards the coast of the British Channel, or of the German Ocean. I do not pretend that the boundary line above given is accurately drawn; nor is accuracy necessary on the present occasion. And, at all events, it is not to be expected, by any one the least acquainted with natural scenery on the great scale, that the strata are bounded by mathematical lines and surfaces: whatever therefore has been hitherto or may be said of their direction and extent, must be taken with some qualification. And, with respect to the term *stratum*, I beg leave to observe, that I shall still continue to use it as descriptive of the integral part of a formation; although no evident traces of stratification should be present in the rocks constituting that formation. Of the two great divisions of this island, formed by the line above described, it will be convenient to me to speak of that first which is on its S. E. side; and in which the stratification is more evident and uniform.

The lowest of the regular formations of this island, which is immediately incumbent on that red rock called by Geologists Rock Marl, so prevalent in many of the central counties, is denominated the *Lias* formation; from a peculiar kind of limestone so called, which occurs in it in thin

beds sometimes of a bluish, sometimes of a light ash colour, alternating with beds of clay or marl.

The formation immediately above the lias consists of numerous alternations of marly clay and sand, and a calcareous freestone; of which the last mentioned member is characterized by numerous minute and nearly spherical particles resembling the roe of a fish; whence it has been denominated Roe-stone or Oolite: and from this calcareous freestone the formation itself has been denominated the *Oolite*. The Bath building stone is among its lowermost strata; the calcareous freestone at the foot of Shotover near Oxford is nearly its uppermost stratum.

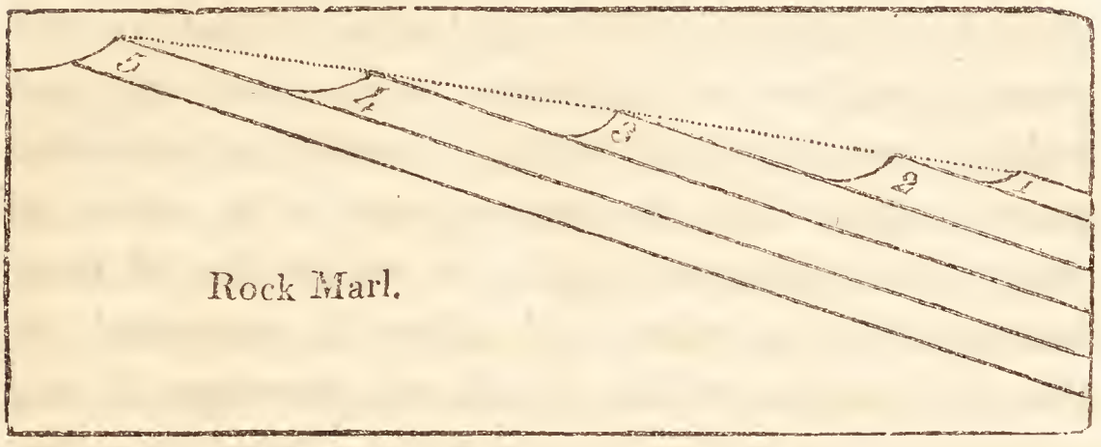
Incumbent on the Oolite is an alternating series of beds of clay, and sand, and calcareous or siliceous freestone, one of the most important of which is the Portland building stone. The same formation contains the fuller's earth of Bedfordshire, and the ochre of Shotover; and is particularly characterized by the occasional presence of small irregularly shaped and generally minute particles of a green substance closely resembling the mineral called Earthy Chlorite; whence the whole formation has been called *Green Sand*. The upper beds of this formation are often charged to a considerable extent with small scales of silvery mica.

Above the suite of beds just described the *chalk* strata occur, which from their decided character may well be considered as a separate formation, though in their lower part they often insensibly graduate into the preceding formation.

Lastly, above the chalk a suite of beds occur of very various character; among the most important of which in this country are a very thick stratum of clay, part of which forms Highgate and Richmond Hill (it is on this clay that London stands; and hence it has been called *the London clay*); and an alternation of beds of sand and loam forming the soil of Bagshot Heath. Of all the above-mentioned formations the escarpments of the chalk and of the Oolite are the boldest and best defined.

A traveller then, in advancing from any point to the N. W. of the line already described, and continuing his journey to the S. E. coast, would almost necessarily cut at right angles all the formations of which I have just spoken. Thus in setting out from Worcester, for instance, which is situated on the rock marl already mentioned, he would first rise upon the *Lias* strata; and, after having travelled for a few miles over an undulating surface very characteristic of that formation, he would ascend the escarpment of the *Oolite* at Broadway Hill: from thence travelling onwards, he would successively pass over the upper beds of that formation, and the beds also of the *Portland* or *Green Sand* suite; till at Stokenchurch he would ascend the escarpment of the *Chalk;* and if he continued his journey in the direction of London towards the isle of Thanet, he would at last ascend upon the strata *above the chalk.* Or, if he should proceed in an opposite direction to that just described, he would successively pass down the escarpments of the upper formations upon

the strata of the lower; each series rising from under the preceding in the following manner.



In the preceding figure the numbers refer to the formations above described; the first applying to the uppermost formation of this island; the second to the Chalk; the third to the Green Sand; the fourth to the Oolite; and the fifth to the Lias: under which is found the Rock Marl: and the dotted line shews the regular descent from the lowermost formation, the lias, to the uppermost, which are above the chalk: so that a river, as actually happens in the case of the Thames, may rise upon the Oolite, which is nearly the lowermost, and terminate upon the uppermost strata of the foregoing suite.

From this arrangement of the strata it appears, as Mr. Townson has observed in his Philosophy of Mineralogy, that the structure of the earth is rather to be described as squamose, like that of the root of a lily, than tunicate, like that of an onion; to which last it has been compared. And there seems an obvious final cause for such an arrangement; for thus, the several strata successively

presenting themselves at the surface of the earth, their contents, often of great value, are brought within human reach; which, had the strata been placed vertically over each other, must in the greater number of instances have been for ever hidden even from our sight. It does not probably ever happen that the escarpment of a series of strata is complete through the whole line of their bearing: it is here and there interrupted by chasms, or even vallies, which cut through it to a greater or less extent; exposing to view on either side a transverse section of the beds composing it. I do not stop here to inquire whether these vallies are of cotemporaneous formation with, or have been excavated since the deposition of the strata: but it is worth observing, that in this way often a passage is afforded to the course of rivers, which otherwise must have been interrupted, and must consequently have overflowed the neighbouring country; till a sufficient quantity of water had accumulated to overtop the barrier. There is another and more obvious final cause observable in the nature of the strata; some being porous; others impervious to water; for hence springs arise: into the general history of which, as dependent on the nature and disposition of the strata, it would not forward my present purpose to enter: but the following circumstance deserves notice, as connected with the object of this publication.

In the Philosophical Transactions for 1717, the sudden subsidence of some oaks in Norfolk is explained from the nature of the soil; which was a gravel resting on sand; and this sand on clay. The

percolated water washing away the sand, the gravel bearing the oaks lost its support, and fell in[g].

In the foregoing account of the strata of the S. E. part of this island, I have been purposely very brief: not only because they have already been described by other authors; but because I have reason to believe that a still more detailed and accurate account of them is likely to be given by a Gentleman, who, from his extensive travels both on the continent and in this island, is most competent to the task; and to whose private but persevering exertions, Geology has long been deeply indebted. The following are among the earliest and most interesting hints I have met with respecting a regularity in the succession of the strata of the earth.

As early as 1684, Lister suggested the plan of a coloured map of England, in which particular colours should represent the predominating character of the strata near the surface; and he adds, "I am of opinion that such upper soils, if natural, *infallibly* produce such under minerals; and for the most part in such order[h]. And then, after having entered into some particulars relative to the stratification of Yorkshire and Nottinghamshire, he suggests the presumption, from the sand which surmounts the chalk in Picardy, that our English chalk was once also surmounted by sand; which has been partly blown away by the prevalence of westerly winds, and partly washed away by rain.

In a paper of the Phil. Trans. for 1722, a Gentleman of the name of Mitchell, in giving an ac-

[g] Philosoph. Transact. 1717, p. 768. [h] Ibid. 1684, p. 739.

count of the fuller's earth pits at Wavendon near Woburn in Bedfordshire, says, "These pits are digged in that ridge of sand hills by Woburn, which near Oxford is called Shotover; and on which lies Newmarket Heath by Cambridge; and which extends itself from east to west, every where, at about the distance of eight or ten miles from the Chiltern Hills, (so called in Bucks and Oxon from their chalky nature,) which in Cambridgeshire are called Gog-Magog; which two ridges you always pass in going from London into the north, north east, or north west counties: after which you come into that vast vale, &c. in which are the Cam, Ouse, Isis, &c. which I take notice of, because it confirms what has been said of the regular disposition of the earth into like strata or layers of matter, commonly through vast tracts: and from whence I make a question whether fuller's earth may not probably be found in other parts of the same ridge of sand-hills, among other like matter[i]."

In the formations of which I have hitherto spoken, there is internal evidence that the planes of separation, by which the strata are kept distinct from each other, are in most instances the result of their successive deposition: but in those formations which are of earlier date than the lias, the planes of separation seem often to depend on the nature of the rock in which they occur. The possibility of the existence of such planes of separation may be illustrated by many familiar instances.

[i] Philosoph. Transact. 1722. p. 419.

Thus a mass of starch after having been dried, and tin after it has been fused and cooled, are each found to be readily separable into distinct though irregularly shaped columns; and the same thing happens to the argillaceous gritstone of Derbyshire, after it has been hardened in a kiln, which is done for the purpose of employing it to mend the roads.

De Luc observes, that some clay which had been collected for a particular purpose, and which had remained a long time undisturbed, had in drying contracted into spherical masses formed of concentric laminæ. I have noticed nearly the same circumstance in the ochre pits of Shotover; where some masses of clay which had been exposed for some time had separated into curved and wavy laminæ. And again, I have even seen a disposition to a concentric parting in a native stratum of argillaceous sand. And I have also often observed, that quicklime, in slowly slaking by exposure to the atmosphere, crumbles away by concentric disintegration so as to develope a succession of spherical masses. And lastly, every one must have noticed in common pastry, that the dough, though previously kneaded in the most arbitrary manner, so as to form a compact homogeneous mass, separates during the application of heat into perfectly distinct and sometimes tolerably regular laminæ: which circumstance probably happens by successive contractions taking place, in proportion as the heat penetrates the substance of the paste, and carries off the moisture.

Again, there is reason to think that original con-

figuration is often brought to view by the action of the air, &c. and that the character of this configuration has led to some confusion in the arrangement of rocks usually called Conglomerates. Thus, by exposure to the weather, flints, and chalk, and the surfaces of natural fissures in soft slate, often present an irregularly concentric arrangement of lines somewhat resembling those of the Egyptian pebble: and many of my readers must be aware that worn pebbles, presenting externally a porphyritic appearance, often present in their fresh fracture a perfectly homogeneous surface both in colour and texture.

Saussure in speaking of the highest summit of the Grimsel, which mountain separates the sources of the Rhone from those of the Aar, says that it consists of a reddish finely laminated gneiss, vertically stratified at the centre, and for some way on each side of the centre; but that near the exterior it abuts against the valley by which it is bounded: so that the strata, if originally all vertical, have dropped away outwards, as when a fan is opened [k]. And on another occasion he says, that the whole of the chain to the south east of the valley of Chamouni, through an extent of seven or eight leagues, has its strata disposed like an open fan; the exterior being nearly horizontal, and having their escarpment towards the valley, but dipping towards the centre of the range. This arrangement, he adds, is of frequent occurrence [l]: and he once observed the same thing in miniature, in the

[k] Saussure, tom. vi. 275. [l] Ibid. tom. iii. 88.

case of a piece of vertical schist, which in weathering at the exposed part spread out like a fan; but was unaltered in the part buried in the earth [m].

With regard to the opinion above expressed, respecting the regularity of the strata to the S. E. of the line already described, and the irregularity of the strata to the N. W. of the same line, I have not met with any one, who has had access to the requisite phenomena, in whom any doubt has arisen respecting the order of succession of the strata in the former division. Of the order of succession of the strata in the latter division, I have neither been able to satisfy myself; nor have I met with any one who could give more than surmises, or an obscure, and at best a partial account of that succession. That there is a regular succession in particular districts, I believe; but, making every allowance for a greater disturbance of the strata in one instance than in the other, it seems reasonable to expect, that, had there been the same original regularity, it would at least have been capable of being traced. But I shall again have occasion to consider this point.

To the N. W. of the *lias* formation, the country soon becomes comparatively mountainous: and in such tracts, in other parts of the world as well as this, not only are the strata ill defined, but there is great irregularity with respect to their escarpments and general line of bearing. Thus Mr. Playfair says, and it is a remark which I have met with in other authors, that the fact of the uniform

[m] Saussure, tom. iii. 278.

direction of the abrupt faces of mountains is often too hastily generalized. In Scotland, as soon as you leave the flat country, the scarps of the hills face indiscriminately all the points of the compass, and are directed as often to the east as to the west[n].

And of the irregularity of the strata in such tracts of country there are endless instances throughout the works of De Luc and Saussure, and many other accurate observers; as I shall hereafter shew. So that Saussure is of opinion that the contortions often visible in some of these strata must have been the effect of crystallization[o]; and in observing that the laminæ of slaty rocks in such districts are often unequal in thickness, or undulated, or folded back upon their original direction, expresses his own opinion, that in the generality of instances crystallization has been the generative cause of these appearances, and of the rocks in which they occur[p]: and in another part he accounts for all degrees of inclination of the strata from a species of crystallization[q]. M. Ramond observes, that the contortions of some of the strata on the northern border of the Pyrenees are often most inexplicable; and that it appears impossible to frame any hypothesis that would satisfactorily account for those contortions. He compares the confusion of their appearance to the effect produced by a mixture of differently coloured glutinous liquors issuing from separate ves-

[n] Playf. Illustr. 410.
[o] Saussure, tom. ii. 194.
[p] Saussure, tom. i. 153.
[q] Ibid. 253.

sels at the same time; or to the convolutions of heavy smoke. He adds, "It is an ocean instantaneously congealed during a tempest, the agitation of which is still expressed in its petrified waves[o]."

But even in ascertaining the existence of stratification, and the degree of inclination of the strata, many difficulties occur. Thus Dr. Mac Culloch, in speaking of the verification of the angle of elevation of strata, says, "It is only in cases where it is necessary to compare particular strata, either with the neighbouring ones or with each other, that accuracy is required; and this accuracy is, I fear, much less frequently attained than pretended to[p]." Saussure also says, that it is extremely difficult to ascertain correctly the inclination of the strata of mountains[q]: and he speaks with caution respecting the criteria of stratification itself. Thus he says precautions are necessary in judging of the real position, so as not to be deceived by fissures. Those are instances of regular strata in which the structure of the rock in the small is parallel with the fissures in the great[r]: and in another part of his work he says, that he only regards as strata, in slaty mountains, those divisions of the rock which are parallel to the laminæ of the slate[s]. Again he says, that true strata are recognized by this circumstance, that the divisions of the beds or strata are parallel to the laminæ of the stone: whereas fissures are commonly at right angles to

[o] Ramond, p. 43, 103, and 104.
[p] Geol. Tr. vol. ii. 452.
[q] Saussure, tom. ii. 9.
[r] Saussure, tom. ii. 24.
[s] Ibid. vi. 317.

the divisions of the laminæ: and as these fissures appear to have taken place while the strata were horizontal, the fissures are consequently vertical when the strata are horizontal, and horizontal when the strata are vertical[t]. On the other hand, however, M. Pini, of whom Saussure speaks very highly, conceives that the divisions which Saussure calls strata are merely accidental[u].

No hypothesis that I have yet met with accounts satisfactorily for the absence of particular strata in different parts of the same formation, or for the inequalities which occur in the dimensions of the same stratum at different points: and the difficulty seems equal, whether we consider those defects and inequalities as cotemporaneous with, and dependent on, the nature of their original deposition, or the effect of subsequent removal.

At Sidmouth, and in that neighbourhood, strata of the green sand are found resting on rock marl; but the intermediate formations of lias, Oolite, and the Portland beds are wanting. Either then they were never deposited; or they have been subsequently swept away: but if swept away, where are their remains? for it cannot be said that the general substance of the strata of those formations was too soft to form a gravel, since the great gravel bed of the neighbourhood of Oxford is principally made up of fragments of some of the same strata: besides which, the whole surface of the surrounding country abounds in fragments of the green sand; and as the strata of this in part still remain in situ, we

[t] Saussure, tom. vii. 68.

[u] Ibid. vii. 98.

might expect to find fragments of the strata which are supposed to have been removed. On the other hand, if it be said that those formations were never deposited in that situation, an equal difficulty arises from the consideration of the extensive deposition of the lias beds within a very few miles of the same spot: to say nothing of the equally extensive deposition of the Portland beds at no great geological distance.

The inequality in the thickness of the same stratum in different parts may sometimes be accounted for on the supposition of a partial removal by water, or any other agent, previously to the deposition of the superincumbent stratum; of which the water-worn channels observable on the upper surface of the Shotover limestone bed, immediately under the superincumbent stratum of clay, is a strong presumptive proof. But then again, the inequality is sometimes such both, in kind and degree, as not to admit of that solution. Thus Saussure describes an alternation of beds of limestone, varying from four to twenty inches in thickness, with thin beds of unctuous slate; in which he noticed this remarkable circumstance, that the thickness of the limestone alternately dilated and contracted, so that the interposed seams of slate represented very regularly waving lines[x]. An arrangement of this kind seems inexplicable on any known principles; for, supposing no alteration to have taken place in the state of these strata since their original deposition, the arrangement is at

[x] Saussure, tom. v. 65.

variance with any experience of which we are in possession: since, although it might have happened that the surface of the lowest of the series should be wavy; (for mechanical depositions will accommodate themselves at first to a considerable angle of inclination;) yet, as Mr. Playfair has observed, the tendency of arrangement in such cases is constantly more and more towards the horizontal line. Or, if it be argued, that these wavy strata were originally deposited horizontally, and that their present arrangement is the effect of compression acting upon them when soft; then, should it even be granted, that a lateral compression would act upon the strata in the same manner as instanced by Sir J. Hall with respect to folds of cloth; yet here the analogy fails: for although it is certainly true that lateral pressure will throw horizontal pieces of cloth into wavy folds, it will not alter the thickness of the cloth itself; a thickening of which kind must have happened in the instance under consideration.

In viewing and comparing the characters of the several strata, it will soon be obvious to the most cursory observer, that some of them abound in the remains of organized matter, whether vegetable or animal, which are seldom or never found in others: and as the presence of these medals of nature, as Saussure has called them, has been supposed never to occur in those formations which till lately have been generally believed to have been the first deposited; hence, on the joint consideration of their priority of deposition, and their pre-existence to the creation

of organized matter, such formations have been called primary; and thus has arisen the great division of the formations into *primary* and *secondary*. Another great division of the formations has arisen from the supposed nature of their origin, or rather the mode of their deposition. In some the arrangement of the constituent particles appears to have been the result of a chemical or crystalline action; in others, of an action merely mechanical: and hence another division of the formations into *mechanical* and *crystalline*; or, as they are also called, *stratified* and *unstratified*.

More accurate observation however has shewn that some of the strata, formerly supposed to be primary, do sometimes abound in organic remains; and if, as has been lately asserted, granite has been found alternating with limestone containing organic remains, the relative age of the former must be given up; nor, however it might disappoint, could it now surprise any one, on any other ground at least than mere novelty, to find organic remains in that hitherto supposed fundamental stratum.

More accurate observation has also given reason to doubt some other positions respecting the mutual connection of the strata and the organic remains contained in them; that connection is at least not so exclusive as has been asserted: for the remains of animals concluded to be characteristic of the newest formations have been found in some of the earlier; and *vice versa*. Thus within the last year the remains of a fossile crab have been found in the Oolite at Stonesfield, which is not much above

the lias beds; and Mr. Townson has mentioned the occurrence of the same fossil even in the rock marl: whereas that fossil had generally been supposed to exist only in the beds above the chalk; and I have myself met with the vertebra of a pentacrinus in one of the uppermost of the Portland beds, though that fossil has scarcely ever yet been found much above the lias. Again, there is reason to think, that besides the remains of crabs and birds and tortoises, which are usually characteristic of the newest strata, the Oolite of Stonesfield contains also the remains of one or more large quadrupeds; which, with the exception in favour of the Paris beds, have only been found in depositions formed above all the regular strata.

But if our knowledge of the actual existence of these organic remains is imperfect, much more so is our knowledge of the origin and mode of that existence; so entirely inexplicable by present experience, and often so contradictory in themselves, are even the most familiar phenomena in this branch of Geology.

In the history of organic remains no consideration is more wonderful, sometimes indeed none more awful, than that perfect state of preservation in which not only the form but the action of the living animal is presented to our view: for the mineralizing process must in such instances have been instantaneous. Thus Faujas, in speaking of the fossile fish of Monte Vestena-nova in the Veronese, says, that among the specimens that have been preserved are one fish in the act of seizing another, and small fossile fish found in the sto-

machs of larger fossile fish; the quarries in which these fossile fish occur being one thousand feet beneath a volcanic mass which surmounts them [y].

In a totally different set of strata, both as to general character and geological position, Leibnitz describes a somewhat similar fact. At Eisleben, a town in Saxony, are quarries in which occur several strata of a kind of slate impregnated with copper pyrites; of which slaty strata, one, and only one, contains the impressions of fossile fish: of these fish, he says, he had in his own hands specimens of a chub, a perch, &c. and not long before his arrival a large pike had been dug out, the body of which was contorted, and the mouth opened, as if the animal had been seized while alive by the petrifying power, and mineralized in the struggles of death. This stratum, which varies in thickness from sixteen inches to the thinnest seam, extends in a horizontal direction through a space of many miles [z].

Dr. Mac Culloch, in speaking of vegetable remains preserved in calcedony, says, "It is worthy of remark, that in almost all the specimens of calcedony which appear to contain aquatic confervæ, not only the vegetable structure is perfectly preserved, but the plant, however light and yielding its texture, is disposed in as free a manner as if still living and floating in the water which was its native element. Together with these circumstances the natural colour is often equally well

[y] Ess. de Geol. vol. i. p. 109.

[z] Leibnitz, vol. ii. part 2. p. 214.

preserved, and the various specimens of the confervæ in particular, which are the plants of most common occurrence, exhibit all the different tones of colour, from the most brilliant grass green to the darkest sap or lightest yellow green, which at present characterize the different living specimens with which we are acquainted[a]." "Whatever were its nature," he adds, "the process here must have been quick; for neither the free disposition nor the forms of the delicate vegetable structure could have been preserved during a slow gradual deposition; nor could the colour have remained unaltered[b]."

There are many other and more familiar phenomena, which are equally inexplicable with the foregoing; as the calcedonic state of some of the fossils of the green sand formation, while the surrounding mass of matter is not calcedonized: and the same observation holds with respect to flint in chalk. So the casts in the striated shell of the chalk described by the Rev. W. Conybeare in the second volume of the Geological Transactions, are siliceous, while the shell itself remains calcareous. But the most remarkable specimen of this kind I have ever seen is a fossile oyster shell brought lately by the Rev. W. Hony from Maestricht. Part of this shell is calcedonized and disposed in concentric rings, like agate; while the rest is scarcely altered from the recent state, being laminated and calcareous. Nor is there a simple line of division between the calcareous and calce-

[a] Geol. Transact. vol. ii. p. 516. [b] Ibid. p. 522.

donized parts; but the former is here and there penetrated by small particles of the latter, inserted after the manner of inlaid work.

At a very great height in the Pyrenees, Ramond met with a sandy rock containing bivalves resembling the cockscomb oyster, and echinites, and gryphites, and ostracites, and buccina: of which he observes that the crested oysters and echinites are siliceous and always broken to pieces; the others are calcareous and very well preserved [c]. Scarcely less difficult of explanation is the fact that many of the shells of the gypsum beds in the basin of Paris are of a marine character, though mixed with others that are apparently fluviatile. This has been ascertained by a naturalist of the name of Brard; who observes, that the complete mixture of the two species creates an apparently insurmountable difficulty [d].

What process of petrifaction, as it is commonly called, will account for the perfect preservation of character in the silicified and opalized wood of Antigua, South America, and other parts of the world? In the first place the instances are extremely rare in which siliceous matter is now deposited from water on extraneous bodies; and we have every reason to suppose, that, like calcareous matter, it would be deposited merely in the form of an incrustation round the exterior of the substance exposed to its action. In this case then, as in those incrusted mosses, and branches of trees,

[c] Ramond, p. 126.
[d] Ann. du Mus. tom. xv. p. 421.

&c. so common in collections, we might have the external form preserved, but no trace of that internal arrangement of concentric and radiating lines which would mark the former growth of the vegetable; yet in some of the specimens of opalized wood to which I have above alluded, in one particularly, belonging to a collection presented to the Ashmole Museum by the Duke of York, nothing can be more delicate than those proofs of the original nature of the mineral.

What again is more inexplicable and capricious than the state of the chalk fossils? some of them broken in various directions, yet scarcely crushed: some of them usually, yet not always, in the state of flint: others rarely, if ever, silicified: some again in a state intermediate to chalk and flint; to say nothing of the remarkable occurrence of those beds of siliceous matter in a stratum that throughout the greater part of its extent is almost entirely calcareous.

What process again is now going on, which would convert the calcareous carbonate of a shell into *fluate of lime*, or *sulphate of baryt*? both of which substances I have found as the mineralizers of organic remains. How shall we reconcile the delicate state of preservation of some substances, with the shattered state of others, in the same stratum, and in the same part of it? How shall we account for the singular fact, that almost all fossile organic remains are of extinct species? for is it not most extraordinary that when all may be supposed to have perished, the traces of those species principally should have been pre-

served, the originals of which have been lost? Supposing for instance that some general catastrophe were at the present moment to overwhelm the earth, and destroy all the living species inhabiting it, with the exception of a few individuals of each, by which the several species might be preserved; but that afterwards some of these species should become extinct: certainly in this case though the remains of the extinct species would hereafter be found probably together with those of the living, yet the latter would occur at least as frequently as the former.

Nothing would be more easy than to multiply accounts equally extraordinary as the foregoing; but enough has been said to shew how utterly inadequate are any known existing processes to the explanation of phenomena of this kind. So that, although these organic remains have been elegantly called by Saussure and others, the medals of nature [e], it must be confessed that they afford but an obscure and imperfect and insulated history even of their own existence.

I proceed now to speak of those internal characters of the strata, which have given rise to their division into crystalline and mechanical formations.

Although in the majority of instances the newer formations, as they are called, appear upon the

[e] Saussure, tom. vi. p. 42.

whole to have been mechanically deposited; yet even among the newest there are not wanting occasional strata, which either throughout their substance, or at least partially, bear marks of a crystalline character. This I think is observable in some of the gypsum beds in the basin of Paris, judging from specimens which I have seen; and in the partial deposition of sulphate of strontian in some of the marls of the same; and of sulphate of baryt in the Highgate clay. The same character is also observable in the lower part of the chalk formation both of this country and of Ireland; and depends on the presence of those green particles which pervade it. These particles have not the form of mechanically worn fragments, but are of a very irregularly nodular form, like some agates; they differ entirely in their nature from any stratum of the neighbourhood from whence they might be supposed to have originated; they disappear and return again in different parts of the same formation in the most arbitrary manner: and lastly, in their chemical characters they agree with the mineral called chlorite; which, though often indeed appearing in an earthy form, is very characteristic of crystalline rocks; being frequent in the highest summits of the Alps.

If we descend from the chalk to examine the suite of the green sand strata, we find these green particles occurring there in a very remarkable proportion; sometimes forming three fourths or four fifths of a whole stratum. Other beds of the same formation are so highly charged with micaceous particles as to resemble the alluvial sand of a granitic

country. Yet there is no evident source either of the micaceous or chloritic particles, unless they be considered as of chemical origin: or if any one should maintain that they are comminuted portions of other rocks, I would not ask where are the remains of those rocks to be found, though the question would be I think allowable; but I would ask, why are these particles entirely wanting in some beds, while they abound in beds adjacent on either side? If from these later formations we turn to the earlier, we still find the same inexplicable association of mechanical and chemical characters; and I believe that what Daubuisson says of some basalts, that they decompose so as to leave hard spherical nodules giving the character of a pudding-stone or conglomerate to the whole[f], is applicable to some other rocks also: and that it still more frequently happens, that the resemblance to a conglomerate depends on the presence of spherical or nodular concretions, which were formed round central nuclei in the original creation, or deposition of the rock in which they are seen.

As I shall again have occasions of speaking on this subject, I shall for the present only dwell on the consideration of those marble breccias, so commonly employed in ornamenting the houses of the nobility and the public buildings of this country about the beginning of the last century.

Saussure says that the term *breccia* has been appropriated by use to such marbles as are apparently made up of angular fragments. The term *conglo-*

[f] Daubuisson, p. 166.

merate has nearly the same import in a more extended sense, being applied not only to marbles, but to all kinds of rocks apparently composed of fragments: it is however more strictly applicable in those instances in which the supposed fragments have been worn smooth to a greater or less degree previously to their union. That aggregation of flint pebbles in a cement of sand so common in Hertfordshire, and known by the name of *plumb-pudding stone* not only in this country but on the continent, is a familiar instance of a conglomerate. In the present volume I use the terms Breccia and Conglomerate merely as descriptive, not believing that the generality of the rocks to which they are applied are composed of the fragments of preexisting rocks; but that they are the result of an original peculiarity of formation.

There are two kinds of the brecciated marbles above referred to, which appear to have been most commonly employed: one of which may be described in general terms as a white statuary marble irregularly interspersed with black veins; the other, as a confused mass of fragments of a white or reddish white marble imbedded in a paste, the predominating colour of which is a purplish brown. In the former of these the veins are sometimes so obscure and of such rare occurrence that the marble may serve for the purposes of statuary; sometimes again the veins are so numerous and so large that they form the principal part of the mass: and between these extremes there is every possible intermediate variety both in the number and dimensions of the veins. For the present purpose I would

call the recollection of my readers to those varieties in which the outline of the separate parts, and of the interposed veins is most distinct: and it will be easily remembered that in such marbles the edges of two nearly contiguous but distinct parts are sometimes so mutually indented, or serrated, as to represent the suture of the bones of the cranium; to which Mr. Playfair has most aptly compared them: and he argues from the appearance that these parts must have been in a state of softness which admitted of such a mutual penetration. To me however there appears to be strong internal evidence that they cannot be considered as actual fragments.

On the assumption then that they are fragments, it must be admitted from the delicacy of their outline, and more particularly from the correspondence in adjacent edges, either that they have not been removed from the spot which they occupied in the body of the native rock; or, if they have been removed, that by a coincidence incalculable even in one particular instance the separated fragments have in numerous instances been brought nearly in contact, in such a manner as to preserve their original relative position almost to a mathematical nicety. But if any one will examine such marbles with attention, he will find that very frequently the correspondence of adjacent edges, though sufficiently close to preclude the supposition that they have belonged to two different lines of fracture, do not yet correspond with any thing like that degree of exactness which they would have done, supposing them to belong to the

same line of fracture. If I should be asked, in what way is the appearance then to be explained, my opinion is this, that some instantaneous agent acting with the celerity of electricity and capable of affecting the colour, and perhaps the nature of the rock submitted to its action, suddenly forced a passage for itself in every direction, so as to give rise to the appearance of *fragments* to those parts round which it played without penetrating their substance; and to the appearance of *veins* in the parts which it penetrated. Where then these veins were accurately defined, and had symmetrical edges, the interposed parts would also have their edges perfectly corresponding, and the projecting and indented angles mutually answering: but where these veins were not accurately defined, or their edges not perfectly symmetrical, the edges of the interposed parts would not exactly correspond.

Some of the foregoing arguments will apply also to the second kind of breccias above described; though in these the distinct parts are often much more confused than in the former: but there are other still stronger arguments. It may, for instance, be repeatedly observed, that the detached parts, though sometimes white, are often of the same colour nearly with the cementing medium; which is a presumption at least of some original connection between them: sometimes again these detached parts and the cementing medium insensibly graduate into the nature of each other's substance: and lastly, which is applicable to both these varieties of marbles, the supposed fragments have their edges sometimes so rounded that they

must, if really fragments, have undergone considerable attrition; and yet they have very far from that regularity of surface which is characteristic of fragments that have actually been rounded by attrition.

I shall not here dwell on the description of the vert antique and the black and white antique marbles; but, referring the reader to my outlines of mineralogy, shall only observe, that the appearances in those marbles are greatly at variance with the idea of their being really breccias.

CHAP. III.

On Mineral Veins.

IF a very thin stratum could be withdrawn entire from a horizontal series to which it belonged, and could then, like a sharp edged instrument, be made to cut through the whole or a part of that series, either in a vertical or oblique direction, it would form what by miners is expressively called a *cross course*. These cross courses vary exceedingly in thickness, and differ equally in the nature and value of their contents; being sometimes the object of the miner's most earnest search, and sometimes the greatest and most dreaded obstacle to his pursuit. In the first instance they are known by numerous appellations expressive of their concomitant effects, as slips, and faults, and troubles; of which technical terms Mr. Farey says there are no less than

seventy: in the last instance they are called *veins*, a term that has evidently arisen from the appearance presented by their transverse section; for strictly speaking it is not applicable to the whole body of the cross course. However it is generally so applied, and therefore I shall use it in that sense. Mr. Williams in his Mineral Kingdom has a good illustration of the nature of veins. If, he says, a bed of brickmaker's clay were spread out and exposed too long to the sun, and into the perpendicular fissures which would thus be formed, by the contraction of the mass, some foreign matter were to be introduced; the matter thus introduced would represent the position of veins or cross courses relatively to the strata in which they occur[a].

There are two prevalent hypotheses respecting the origin of veins: according to one it is supposed that they were injected among the strata in a state of igneous fusion from below; according to the other, that they were formed by infiltration from above: but it has probably been too hastily assumed that these veins or cross courses have been of subsequent formation to the strata which they traverse: many acute and experienced Geologists at least are at the present day disposed to allow, that in various instances they must have been of cotemporaneous formation with the strata themselves; the evidence in favour of which opinion, together with some of the most general phenomena of veins, I propose now to examine.

[a] Mineral Kingdom, vol i. p. 34.

It will not be irrelevant to the present question here to mention an appearance which, though necessarily of very common occurrence, I never had an opportunity of witnessing in a favourable manner till last summer. In passing along the path of a field, the soil of which is a stiff clay, I observed a very narrow but regular crevice running longitudinally through the middle of the path. I at first supposed that it had been formed by some fine-edged cutting instrument drawn along the surface; but upon a closer inspection I found that it was a fissure naturally formed by the contraction of the clay; the dry season having lately commenced. In the course of a few days the longitudinal crevice had increased in its breadth; and the process of contraction in the clay having advanced, numerous lateral crevices had taken place, which at one extremity opened into the main crevice at nearly right angles; and towards the other extremity became gradually narrower till they were insensibly lost. There was one circumstance attending the appearance I have been describing particularly illustrative of the subject now under consideration. In parts of the path the longitudinal crevice separated into two branches; which, first diverging from each other and afterwards gradually approaching till they met, were then continued in the original direction; thus inclosing, between the points of their division and reunion, a space of an oval form, very accurately representing the section of what in technical language is called a *rider*: and a similar circumstance was also observable in some of the lateral crevices. It

is further deserving of notice, that the diameter of the same crevice varied considerably in different parts of its course. In the preceding instance any portion of the longitudinal crevice, together with the accompanying lateral crevices opening into it, gave a tolerably accurate representation of the section of a similar arrangement of mineral veins: but in such an arrangement it is usually maintained that the continuous vein has divided the intercepted veins, and that therefore it must have been of posterior formation to them; whereas in the actual arrangement of which I have spoken, the intercepted veins were certainly of posterior formation to the continuous vein. Although then it is not to be denied that a line, which has been divided by another, must have existed previously to that division; (any more than that in a mass made up of fragments those fragments must have once been separate;) yet it seems probable that in geological speculations the terms *divided* and *dividing* may possibly be applied on the assumption that the senses cannot be deceived as to appearances; which, from what has been above said, it appears may possibly happen. So with respect to agates the terms *containing* and *contained*, if they are intended to imply priority of formation, may possibly be erroneous. Perhaps indeed, as I have supposed in the case of veined marbles, some unknown agent, analogous to electricity in its rapidity and power of operation, may have acted upon the strata so as to produce veins, by penetrating them in a variety of directions, and altering the composition and character of the penetrated

part. This idea receives some confirmation from the account of the vitreous tubes found at Drigg, in Cumberland, in some hillocks of drifted sand[b]. These tubes, which appear to have been the effect of lightning, descended perpendicularly through the sand; they tapered in their descent; separated into branches terminating in threads; and in one instance, the course of the lightning having been intercepted by a fragment of hornstone porphyry, the tube formed by it glanced off from the fragment at an angle of about forty-five degrees and then returned to its former vertical position[c].

If veins have once been fissures which have subsequently been filled with metallic ore, &c.; then although a vein crossing another might throw one or both of the divided parts out of their original direction, it does not seem possible that the dividing vein could alter the nature of the divided vein: yet Mr. Phillips says that in Cornwall a metalliferous vein is frequently found to be poor on one side of a cross course which intersects it, though rich on the other[d]. And in another place he says that a cross course, passing continuously through two different rocks, is of different dimensions and of a different character in one from what it is in the other[e]. Equally unfavourable either to the hypothesis of infiltration from above, or injection from below, are the following facts. It is stated by Mr. Phillips, that if in Cornwall two metalliferous veins

[b] Geol. Transact. vol. ii. p. 528.
[c] Ibid. p. 528, 529.
[d] Ibid. p. 135.
[e] Ibid. p. 151.

dip in *opposite* directions so as to meet under ground; it is generally found, that, though they might have been rich when separate, they are poor at and after their junction: but if they dip in the *same* direction, and one of them quicker than the other, it is generally found that when the one overtakes the other they seem mutually to enrich each other[f]. The same gentleman says, that in a vein nine feet wide, the mass of which was principally compact quartz, the quartz has been known in one instance on a sudden to assume the form of a fine sand[g]. In several instances a copper vein has been found to cease as suddenly as if it had been cut away by a hatchet; and this not the effect of a cross vein, but purely one of those accidental circumstances to which copper veins in Cornwall are very liable[h]. Lastly I would observe, from the same authority, that when two or more mines are on the same vein or veins, there is frequently but little else that is common to each; and even in the same mine, situated between a few superficial acres, there is often a strange variety in the dimensions, contents, and direction of its veins, as also of the rocks, through which these veins run[i]: so that in the whole range of the employments of man there is not perhaps another in which experience and ingenuity are more often and completely baffled than in mining; for there is scarcely one symptom in which the miner most relies that has not occasionally deceived him[k].

[f] Geol. Transact. vol. ii. p. 115. [g] Ibid. p. 160.
[h] Ibid. p. 129. [i] Ibid. p. 113. [k] Ibid. p. 120.

The phenomena of veins in Derbyshire are as extraordinary as in Cornwall. What hypothesis for instance will account for the singular fact, that in a series of successive strata, alternately consisting of limestones, and of rocks of a different character, the metalliferous veins are present in the limestones but not in the other rocks; which fact is still more singular from this circumstance, that the larger veins of the limestones, though not continued into the stratum either above or below, send filaments as it were from themselves into each. It is moreover remarkable that the veins are also completely cut off by seams of clay called wayboards, which occur in the body of the limestones, beyond which seams they are continued. Again, the veins are thicker and more productive of ore in some than in other beds of the same limestones; and where a vein has been cut off it is rarely continued on the other side of the intercepting rock in the same line; nor does it often happen that either its character, or dimensions, are the same as previously to its interruption[l]. An old and experienced captain of mines told De Luc that the same vein in the Cornish mines varies very irregularly in its thickness; and in passing through a rock differs in richness according to the colour of the rock: and De Luc observes that the same difference in richness is noted in other countries when the same vein passes through different strata[m]. The mountain called the Rammelsberg on the extreme confines of the Hartz, near Goslar, contains

[l] Farey, vol. i. p. 249. [m] De Luc's Travels, vol. iii. p. 259.

two large veins which inclose an immense mass of the rock technically called a rider; respecting which De Luc justly asks, "If the space occupied by these veins was once void, how did the interposed mass of rock then support itself? for usually in such instances, in removing the matter of the vein, the rider sinks and occasions much damage[n]." With respect to these riders themselves, Mr. Farey, in describing them as formed by the division and subsequent reunion of the divided parts of a vein, being the large lenticular mass which occupies the space formed by the above separation, says, that they are by no means of the same character with the rock in which they occur; being a confused crystalline mass sometimes without any ore or perfect spar[o]. As explanatory of the term *rider*, which is certainly used incorrectly, I subjoin the following paragraph from the paper in the second volume of the Geological Transactions, by Mr. Phillips, already referred to. "When the division of a perpendicular or nearly perpendicular vein takes place, the two branches of the vein bestride as it were the intervening mass; and hence the Cornish miners call that intervening mass a *horse*; and the phrase in meeting with it is, the load or vein has taken horse[p]."

Among an endless variety of inexplicable circumstances attending the phenomena of veins I shall only add the few following, as evincing the difficulty of the subject. Humboldt mentions a singular instance of a principal mine in Mexico,

[n] Lettres, tom. iii. p. 362, 361.
[o] Farey, vol. i. p. 248.
[p] Geol. Transact. vol. ii. p. 129.

which is traversed by a number of small soft and argillaceous veins so remarkably rich in gold disseminated through them in impalpable particles, that when the miners, who work without any covering, come out of the mine, they are obliged by the overseers to wash themselves in tubs appropriated to the purpose, to prevent them from carrying away the auriferous clay adhering to their bodies[q]. The metalliferous veins of Cornwall run generally east and west: the veins called cross courses, from the circumstance of their traversing the former, and which consequently run north and south, rarely produce any metallic substance; yet in one mine they universally produced tin[r]. A metalliferous vein, having granite as one wall and schist as the other, sometimes contains in itself detached masses both of schist and granite: and frequently a vein in schist will contain detached masses of granite; and a vein in granite detached masses of schist[s]. There is a blackish limestone on the borders of the lake of Geneva, near Meillerie, almost opposite Lausanne, which often contains veins of white calcareous spar: it is singular that these veins when rubbed emit a bituminous smell, though the black stone itself when rubbed emits no smell[t]. As naturally connected with the history of veins I may mention the uncertainty respecting the occurrence of similar veins in similar rocks, in different or even in the same parts of the world. Thus in some instances the transition

[q] Humboldt, tom. iii. p. 349. [r] Geol. Transact. vol. ii. p. 134, 135.
[s] Geol. Transact. vol. ii. p. 155. [t] Saussure, tom. i. p. 356.

strata of Werner, a term which I shall presently explain, are remarkably metalliferous; in others they do not produce a particle of ore, with the exception at least of iron pyrites which is present almost every where. Within fifty years it was in Cornwall considered hopeless to find copper in granite; but experience has shewn in many instances that copper is found in granite[u]. Humboldt says that there is as great a degree of inequality in the richness of the metallic veins of America, as in those of Europe. Thus in America, as well as in Europe, there are vast tracts even among metalliferous mountains, in which not a single vein is found; and $\frac{19}{20}$ of the American mines are very poor[x]. He also says that tin has never been found in the granite of Mexico, to which rock it is almost peculiar in Europe; and that wood tin, the rarest form of that metal in Europe, is its commonest form in Mexico[y].

Finally, such phenomena, as insulated crystals of one substance, imbedded either partially or entirely in the body of another, are among those appearances which our present state of knowledge seems utterly incapable of explaining. Thus Saussure met with fine white brilliant fibres of amianthus penetrating an ore of manganese, where neither serpentine, nor steatite, nor any other magnesian rock, occurs in the neighbourhood[z]. Of the same character are those well known specimens of quartz containing most delicately capillary crystals

[u] Geol. Transact. vol. ii. p. 131. [x] Humboldt, vol. iii. p. 336.
[y] Humboldt, Engl. Trans. vol. iii. p. 130, and 229.
[z] Saussure, tom. viii. 232.

of titanium; in which though it is impossible to conceive that the quartz could have been deposited round the insulated crystals, it is also impossible to conceive from whence, after the formation of the quartz, the titanium originated: so that in this as in many other instances we must, for the present at least, take refuge in the conclusion, that they are the result of some creative act, the nature of which we shall in vain attempt to investigate; a mode of reasoning, to which though it would be unworthy of our nature ever to resort without an effort to comprehend the secondary means employed by the Deity in the arrangement of the material world; yet of which it would be presumptuous and equally unworthy of our nature to suppose we can ever be entirely independent.

CHAP. IV.

On Werner's Classification of the Strata.

HAVING spoken of the formations situated to the south east of the boundary line of the strata of this island originally described, and having considered some of the phenomena accidental to the strata in general, it would be here in order to proceed to the formations, situated to the north west of the same line. But as almost all the rocks of those formations are known to occur in various other parts of the world, and are described in the works of Saussure and other Geologists, I shall include the particular history of those formations in

the general history of the rocks of which they are constituted. I shall first however offer a very short outline of Werner's classification of the strata, which has been taken from the valuable geological treatise of Professor Jameson[z]; in which if I have unintentionally misrepresented any statement of that able disciple of Werner, I claim his indulgence.

Werner divides rocks into five classes, called *Primitive*, *Transition*, *Flœtz*, *Alluvial*, and *Volcanic*. The first class contains those rocks which are supposed to have been deposited from the chaotic fluid which originally enveloped the earth, antecedently to the creation of living beings. They are of a character almost exclusively chemical, and do not contain organic remains of any kind. The second class contain those rocks which are supposed to have been formed during the transition of the earth from its chaotic to its habitable state. These are partly chemical and partly mechanical formations; and contain not only fragments of the preexisting rocks, but occasionally organic remains of some of the low orders of animals. The third class contains those rocks supposed to have been formed while animals and vegetables existed in great numbers. These, which are also partly chemical and partly mechanical, and often abound in organic remains, are denominated Flœtz rocks; because they are generally disposed in horizontal or *flat* strata. The fourth class, called Alluvial, comprehends not only depositions of silth &c. from

[z] Jameson, vol. iii. p. 99.

rivers, and accumulations of peat and various other substances which are actually now in the progress of formation; but also beds of gravel. The fifth class contains true volcanic rocks, as varieties of lava; and pseudo-volcanic rocks, as burnt clay &c. resulting from the effect of the combustion of coal strata.

The principal of Werner's primitive rocks are granite, gneiss, micaceous schist, argillaceous schist (of which roofing slate is a common variety), primitive limestone (of which statuary marble is a variety), primitive trapp (consisting chiefly of the mineral called hornblende), serpentine, porphyry, and syenite. And most if not all of these rocks, with the exception of primitive limestone, occur in Cornwall. Syenite occurs in Leicestershire, at Mount Sorrel; and in Worcestershire, at Malvern; and, I believe, in Somersetshire, near Taunton. The principal of his transition rocks are a compact dark coloured limestone; a trapp rock consisting usually of a compact felspar, coloured by different proportions of hornblende, and containing agates, &c.; and a rock to which the Germans have given the name of *grauwacke;* and which, by English mineralogists of the present day, is generally supposed to be either a slate, the particles of which have been mechanically aggregated; or a conglomerate, made up of sand or pebbles more or less worn, with or without an intermediate cementing paste. The rocks of the transition formation appear to prevail more or less extensively throughout the greater part of the Western coast of England; abounding

particularly in the north of Devonshire, in St. Bride's bay, and in Cumberland. Werner's third class is not, I think, clearly definable with reference to the stratification of England; but it certainly includes that red rock so prevalent in the central parts of this Island, together with the depositions of *rock salt* and *gypsum* contained in it: it also includes the several *coal fields*, as they are called, which occur in the north west division of England: and it also necessarily comprehends *all* the formations of the south east division of this Island above described. The fourth and fifth classes of Werner require no further description than has been already given.

All the principal rocks of Werner's first class are in general so well characterized, as to be easily recognized by a Geologist of any experience: but much confusion exists with respect to many rocks belonging to the second and third class; of which I shall hereafter speak more at large. In proceeding to describe the rocks constituting the irregular strata of this, and other parts of the world, I shall begin with granite; which till lately has been very generally allowed to be the oldest or lowermost of all the strata.

CHAP. V.

On Granite.

FAUJAS asserts that Saussure, Dolomieu, and Patrin, as well as himself, were convinced that the

term granite comprehended not only true granite, but gneiss, slate, porphyry, and all kinds of hornblende rocks[a]; and I believe there is that degree of connection between those several rocks which justifies the application of the term granitic to all of them: but though the application may be founded in truth, it is founded in a truth of that nature which, in order to insure its reception, must be gradually unfolded to the mind. I propose therefore in the first instance to examine the character of those rocks to which Saussure and others have applied the term granite.

Saussure then, although he gives the name of granite preeminently to a compound of quartz, felspar, and mica, yet observes that other ingredients occasionally enter into its composition[b]; and he calls by the name of granite a rock composed of flesh-coloured felspar with quartz, mica, and greenish hornblende; and says that he has seen granites of this kind in the Vosges, as well as in the Alps[c]. As he however adds that in the granite of this kind which he saw in the Vosges the hornblende was disposed in radii, it may here be said perhaps that a radiated crystallization is more descriptive of tourmaline than of hornblende; and considering the occasional close resemblance of the two minerals, it is possible that even Saussure may have been mistaken: but it is clear that if he gave the name of a granite to a compound containing *hornblende* in addition to the three usual

[a] Essai de Geol. tom. ii. p. 151, 155.

[b] Saussure, tom. i. p. 146. [c] Ibid. tom. ii. p. 224.

constituent parts, he would not have refused the same name to a similar rock containg *tourmaline*; for the frequent occurrence of this mineral in true granite is well known. Again, in the republic of Urseren, near the confines of the Canton of Uri, he met with a granite containing green earth passing sometimes into crystallized hornblende[d]; and he observes of the granite very near the summit of Mont Blanc that it frequently is mixed with greenish or blackish hornblende, and also with masses of chlorite; the hornblende and the chlorite appearing to supply the place of mica, which occurs but seldom, and then only in small particles: and he adds, that this granite contains also veins of a compound of black hornblende and grey felspar, and particles of epidote[e].

Again he says, that the rocks near the summit of Mont Blanc are granites in which the felspar constitutes nearly three fourths of the whole mass, and the quartz about one fourth; hornblende and steatite holding the place of mica, which occurs in very small particles; if indeed those particles are mica, which is doubtful[f]. I would here remark by the way that in many rocks of a granitic character in which hornblende is a constituent part, a micaceous substance having the lustre of bronze, and by no means the smoothness and elasticity of true mica, is often observable. Such is the catgold, as it is sometimes called, of a part of Malvern Hill. Saussure adds with respect to the granitic

[d] Saussure, tom. vii. p. 85. [e] Ibid. p. 273, 274.
[f] Ibid. p. 273, 274.

rocks near the summit of Mont Blanc, that all their natural divisions or rifts are superficially covered with a chloritic incrustation of a green or blackish colour[g]. On another occasion he states, that a very common variety of the Alpine granite is a mixture of quartz and shorl[h]; which rock may satisfactorily I think be shewn to be really a compound of hornblende and felspar: for when he says that the shorl is most frequently crystallized in rectangular laminæ; that all the shorls of the neighbourhood of Geneva affect the magnetic needle[i]; and that the colour of the compound is black, green, or brown; no one I apprehend will refuse to acknowledge the probability that hornblende may be in this instance the colouring principle, considering that the description of the crystalline rectangular laminæ and the magnetical property are closely applicable to that substance. But to put the matter out of doubt, having in another part of his work described a similar rock, he subsequently corrects his former statement with respect to one of its component parts, owning that what he mistook for quartz was really *felspar*; the mistake arising from the difficulty in perceiving the laminated texture of the felspar[k]: and in another place he says the compound of greenish black *hornblende* and whitish *felspar* is a kind of granite; and is in Italy known by the name of granitello[l].

[g] Saussure, tom. vii. p. 280, 282.
[h] Ibid. tom. i. p. 141.
[i] Ibid. tom. i. p. 88.
[k] Ibid. tom. vi. p. 73.
[l] Ibid. tom. vi. p. 74.

It may be collected then from the foregoing and other passages that though perfect granite in the nomenclature of Saussure consists only of quartz, felspar, and mica; yet he also continues to apply the name although either tourmaline, hornblende, green earth, chlorite, steatite, or epidote should be superadded; and even in cases where the place of mica, one of the genuine constituents of granite, is almost entirely supplied by an accessary principle. And in support of the opinion, that these various rocks may have a natural alliance, it is observed by Saussure, that a greater diversity and more sudden transitions may naturally be expected in the character of crystalline rocks than in those of mechanical origin [m].

I proceed now to examine some peculiarities in the proportions and crystallization of the constituent parts of granite; but more particularly its transition into rocks of a different character: and with respect to the first of these points Saussure observes, that in some parts of a granitic rock scarcely any thing is present but *mica*; in other parts scarcely any thing but *quartz* (and he even gives an instance of a vein of granite occurring in quartz [n]); in others again, scarcely any thing but *felspar* [o]; and he instances the high summits of the Alps generally, in which the relative proportion, and the size and the colour of each of the three constituent parts, vary very considerably [p]. The following circumstance, though characterized by

[m] Saussure, tom. iii. p. 99.
[n] Ibid. tom. vii. p. 84.
[o] Ibid. tom. i. p. 139.
[p] Ibid. tom. i. p. 144.

Saussure as important, is not uncommon in the Alps. On the eastern bank of the Rhone, to the north of the point where it is joined by the Isere, and near the spot where the hermitage grape grows, is a granite, in the crystals of the quartz and felspar of which mica is imbedded[q]. I have observed the same fact in the felspar of the granite of Dartmoor; and I remember once seeing in Mr. Heuland's superb collection a large and well defined crystal of felspar, through the substance of which quartz and mica were disseminated in such quantity, and with such regularity, as to constitute with the felspar itself a true granite.

With respect to the different degrees of induration of granite it is observed by De Luc, that much of the granite both of the Alps and of the Hartz very readily undergoes disintegration[r]; and in speaking of a hill between Deventer and Delden, which he considers as an aboriginal hill of granite, he says its nature is so friable as to leave it in doubt whether it is a native stratum or a heap of gravel[s]. In his travels in England, when speaking of the loosely compacted granite of Dartmoor, he says that it resembles varieties of granite which he has seen in the Alps and in many mountains of Germany[t]. To the foregoing statement of De Luc I may add from my own experience, that the road across Dartmoor from Ashburton to Chagford has in one part been cut through such a loosely com-

[q] Saussure, tom. vi. p. 186. [r] De Luc, Lettres, tom iii. p. 469.
[s] De Luc, Lettres, tom. iii. p. 468.
[t] De Luc's Travels, vol. iii. p. 131.

pacted granite as has been above described: and certainly from the state of its aggregation it might at first be easily mistaken for gravel; since upon the slightest attempt to remove any part it crumbles into a coarse sand: but when viewed attentively in its native bed, its real nature may be easily recognized from the undisturbed outline of well defined crystals of felspar contained in it; though the substance of those crystals is as loosely aggregated as any other part of the rock. In Cornwall such soft granite is called *grouan,* the original signification of which word is said to be *gravel.* Saussure, as well as De Luc, observes, that granite varies in its state of aggregation from the hardest rock to mere loose gravel: and he adds, that though granite of this soft kind is not common in the Alps, it is very common and occurs for leagues in extent in other mountain chains[u].

A far more important point in the history of granite, than either its mode of crystallization or its state of aggregation, is its transition into rocks of a different character. Such transitions are by no means unfrequent, and sometimes take place very abruptly. Thus the tourmaline, which is frequently found diffused in crystals, single or grouped, through the granite of Dartmoor, is sometimes accumulated in so great a proportion as to exclude the other constituent parts; and hence you not unfrequently find insulated patches of nearly a black colour, and a close grained texture, in the midst of a granite principally composed of large

[u] Saussure, tom. i. p. 145.

and distinct crystals of white felspar. This, which probably happens in many parts of Dartmoor, I observed in the granitic hill from which you descend into Chagford on the Ashburton side.

Saussure on several occasions speaks of the gradual transition of granite into schist[x]: and in the passage last referred to, having alluded to such a transition, and having described three varieties of schist which often effervesce with acids, he adds that these three gradations, together with granite itself, sometimes do not occupy more than a foot in thickness[y]. And from this transition he argues on another occasion as to the relative age of the strata in which it takes place; observing that although as a general position it may be true that granite is older than gneiss, yet it is evident from their mutual transition, and interstratification, and similarity in degree of inclination, that gneiss is occasionally as old as granite[z]. This gradual transition of granite into other rocks frequently, he says, takes place by admixture of hornblende[a]: and he gives one remarkable instance of a peak, "L'aiguille des Charmoz," situated above Montanvert and the Glacier des Bois in the valley of Chamouni, which is composed of granite insensibly becoming softer by admixture of hornblende[b]. The granite occurring near the sources of the Aar and of the Rhone, not far from St. Gothard, is intermixed with rocks composed of hornblende and felspar[c].

[x] Saussure, tom. i. p. 345, and ii. 228, and iv. 45.
[y] Ibid. tom. iv. p. 45.
[z] Ibid. tom. vii. p. 98.
[a] Ibid. tom. ii. p. 228.
[b] Ibid. tom. ii. p. 333.
[c] Ibid. tom. vi. p. 257.

The summit called "Le dôme du Gouté," which is very near Mont Blanc, contains decomposing hornblende which gives a ferruginous colour to the surface of the rock: its other constituent part is felspar[d]. The rocks at and near the summit of the Col de Geant, which is one of the highest eminences near Mont Blanc, much resemble those of Mont Blanc; chlorite supplying the place of mica, and sometimes the felspar, sometimes the quartz, predominating. In these rocks epidote occurs acicularly crystallized[e]. And in ascending Mont Blanc Saussure met with gneiss alternating with a schistose rock consisting of hornblende and felspar[f].

The contiguity of schistose rocks and granite is exceedingly common. Thus the lowest and most northerly of a small chain of rocks, insulated in the midst of the ice of Mont Blanc, was a schistose rock consisting of laminated hornblende of a greenish or blackish colour, and of felspar; with occasionally quartz and mica[g]. Argillaceous schists like roofing slate, occur also in the same chain[h]. Saussure has also observed granite passing into rocks of a talcose character[i].

[d] Saussure, tom. vii. p. 261, &c.
[e] Ibid. p. 380.
[f] Ibid. p. 247.
[g] Ibid. p. 253.
[h] Ibid. p. 253.
[i] Ibid. tom. iii. p. 112.

CHAP. VI.

On Syenite.

THE term Syenite is applied by modern mineralogists to rocks which consist principally of hornblende and felspar: and though by some it is restricted to those varieties in which the felspar predominates, and is of a red colour, of which character the rocks about *Syene* in Upper Egypt appear to be; yet by many it is applied to those varieties also in which the hornblende predominates, and the felspar is nearly white: but this last variety is more commonly called greenstone, from the prevailing colour of the hornblende; which colour however is often nearly black.

Red syenite, according to my own observation, if it contain mica and quartz, especially should the proportion of hornblende be small, so closely resembles true granite, that in detached parts the most experienced eye could not easily detect the difference: as is the case in some of the syenite of the island of Jersey. The other variety of syenite, which is a compound of dark coloured hornblende and white felspar, has been above shewn on the authority of Saussure to be the granitello of the Italians: and fine-grained crystallized specimens of the same compound, in which the constituent parts are equably diffused through the mass, and in which the colour of the hornblende is green, answer in some instances to the granite of the ancients.

As far as I can collect from actual observation and from reading, there is a tolerable degree of uniformity in the general colour of either of the above-mentioned varieties of syenite, as observed in the same district; so long at least as the compound is distinctly of a crystalline structure. Thus in the syenite of Malvern a red colour prevails: in the syenite of St. David's, Pembrokeshire, a green or blackish colour prevails. Each variety however occasionally passes into the other, as happens in some parts of the isle of Sercq according to Dr. Mac Culloch[k].

Considering then syenite as consisting principally of felspar and hornblende, it will be found that like granite it often contains other accidental component parts; of which some of the commonest are mica, epidote, quartz, steatite, and chlorite. Like granite also it displays an infinite variety in the characters and proportions of its constituent parts: thus De Luc, in speaking of a great accumulation of loose blocks of stone near Potsdam, says that they are commonly fragments of a rock consisting of red felspar and black hornblende; and that the proportions of the two component parts, and the form of their distribution, sometimes into spots, sometimes into stripes, exhibit every possible variety[l].

And lastly, like granite it is found to pass by very gradual transitions into rocks of a very different character; and often abruptly alternates

[k] Geol. Transact. vol. i. p. 16.

[l] De Luc's, vol. v. p. 309.

with schists of various kinds. Thus Mr. Farey, in stating that there are several patches of syenite in Leicestershire, besides that of Mount Sorrel, observes, that the abrupt transition from slate to syenite in the same hill is not unfrequent; and that this slate in decomposing often assumes the external character of syenite, presenting the appearance of the compound mass[m].

CHAP. VII.

On Hornblende Rocks.

No mineral appears to be of more frequent occurrence in the earlier series of rocks than hornblende; and, though not exclusively, it is more particularly associated with felspar, than with any other mineral. It happens that although many among the class of rocks, of which hornblende forms a principal constituent part, are capable of being very precisely defined, yet the greater number are very obscurely characterized: and hence the difficulty of recognizing them by a verbal description; and the consequent confusion that has arisen from a comparison of different authors. I cannot hope to remedy a difficulty of such extent; but having from particular circumstances been led to examine the question with greater care than would have been necessary in general, I am induced to give the result of my inquiry.

[m] Farey, vol. i. p. 154.

In that variety of syenite in which the hornblende usually predominates, the felspar is often evanescent; in which case, though felspar itself, or one or two other constituent parts, may be present, as mica or steatite, yet if the proportion of these be very small, the rock may consistently with common usage be denominated simply *hornblende:* and its specific character would depend upon its degree of crystallization, or state of aggregation. Hence we have *highly crystallized* hornblende, *schistose* hornblende, and *compact* hornblende.

If the hornblende and felspar be each in a minute state of division, and in nearly equal proportions, and intimately mixed, then the compound is of that nature which is generally described by foreign mineralogists under the terms *roche de corne; pierre de corne; corneus trapezius;* and, generically, *trapp.* Thus Saussure, in speaking of a compound of hornblende and felspar, describes the particles as so minute that it might be called a trapp[n]; and in another part he describes a trapp as a rock composed of small heterogeneous particles, aggregated without the appearance of any regular crystals[o]. But the same terms are frequently applied to those rocks also in which hornblende is nearly the sole constituent part. Thus we have in Saussure *pierre de corne en masse; corneus fissilis;* and *corneus spathosus;* as expressive of compact, slaty, and sparry, or crystallized hornblende[p]. Thus

[n] Saussure, tom. vii. p. 287.

[o] Ibid. tom. vii. p. 203.

[p] Ibid. tom. i. p. 96, 97.

also in the Hartz collection of the geological society the term trapp, though applied to varieties of toadstones and amygdaloids, is also applied to hornblende rocks, and basalt: which last in Daubuisson's opinion is sometimes little else than compact hornblende[q]. Saussure again sometimes uses the terms roche de corne and hornblende schist as synonymous[r]; and when on one occasion he makes a distinction between them, it nearly comes in support of the opinion I have above stated. "*Pierre de corne schisteuse*, or *cornéenne*, he says, only preserves this name when its texture, whether it be schistose, or compact, is perfectly homogeneous: when it has distinct parts, bearing signs of crystallization, it takes the name of *hornblende*[s]."

Ferrara in his history of Etna says, that the remains of ancient sculpture at Rome worked in Egyptian basalt shew that this basalt is a species of *trapp*, or of the rocks called *sassi cornei*, containing crystals of black shorl (hornblende)[t]. Daubuisson says that Werner comprehends greenstone (i. e. a compound of white felspar and dark coloured hornblende) under the generic term *trapp*. Lastly, Jameson says that Werner restricts the term trapp to rocks principally characterized by the presence of *hornblende* and black iron *clay*: but in the oldest trapp rocks there is no iron clay, the clay increasing in the newer formations[u].

[q] Daubuisson, p. 113.
[r] Saussure, tom. vi. p. 257.
[s] Saussure, tom. v. p. 78.
[t] Ferrara, p. 302.
[u] Jameson, vol. iii. p. 129.

And according to the same author primitive trapp includes rocks of greenstone, hornblende rock, hornblende slate, and greenstone slate[x].

There appears to be the same endless variety in the internal character of the class of rocks I am now considering that has been observed in those already spoken of; particularly however, according to Saussure, with respect to colour[y]. There appears to be also the same both insensible and abrupt transition into, as well as alternation with, rocks of a different class. Thus in the chain adjoining that of Mont Blanc, trapp rocks of a green colour together with beds of dark coloured syenite are found intermixed with, and parallel to, beds of slate[z]. In another part of his work he says, that hornblende forms the base of the rocks, not only at the foot but even towards the summit of Mont Blanc; and these rocks approach nearer to the character of roofing slates, than any he had hitherto seen[a]. In a subsequent volume he says, that among the rocks nearest the summit of Mont Blanc, which summit is a very narrow and nearly horizontal ridge entirely covered with snow, he met with a compound of hornblende and felspar, in which the particles were so minute that it might be called a trapp[b]. And among the same rocks were varieties of dark coloured syenite, in which the hornblende predominated, and the whole structure was slaty; and fine-grained soft hornblende slates of a greyish green colour, in which the la-

[x] Jameson, vol. iii. p. 117.
[y] Saussure, tom. i. p. 97.
[z] Saussure, tom. iii. p. 223, 240.
[a] Ibid. tom. iv. 467—469.
[b] Ibid. tom. vii. p. 287.

minæ were sometimes undulated, and interspersed with thin plates of white felspar[c]. Here then we find varieties of trapp rocks nearly at the very summit of the central chain of the Alps: and Dr. Mac Culloch states also, that hornblende slate is known to be common in gneiss and granite[d].

A remarkable instance is given by Dr. Mac Culloch of a connection existing between a bed of limestone and a hornblende slate in the micaceous schist of the Highlands; the limestone being penetrated by crystals of the hornblende not only where it comes nearly in contact with it, but also to near its centre[e]. In like manner it is stated by Vauquelin, that the substance of the dolomite is so intimately mixed with even the interior of the crystals of grammatite or tremolite occurring in it, and in different instances in such different proportions, that it is impossible to obtain constant results in the analysis[f]. I shall have occasion to consider some other points in the history of hornblende rocks in the chapter on schists.

CHAP. VIII.

On Serpentine.

BEING persuaded of the connection that exists between hornblende rocks and serpentine; which, I believe, may, in this island, be very satisfactorily

[c] Saussure, tom. vii. p. 287. [d] Geol. Transact. vol. i. p. 16.
[e] Geol. Transact. vol. ii. p. 436. [f] Ann. du Mus. tom. vi. p. 232.

traced, both in Cornwall and North Wales, I am happy in adding that I have the authority both of Saussure and Mr. Jameson in support of my opinion. Mr. Jameson indeed distinctly allows that *serpentine* is very nearly allied to the rocks of the *trapp* formation[g]: and there are many passages in Saussure and other authors which justify the supposition of a natural connection between them. Thus to the S. E. of Aoste there occur repeated alternations of steatite and hornblende rock according to Saussure, who, it should be observed, uses the term steatite as synonymous with serpentine[h]. And in the same neighbourhood he found serpentine assuming the appearance of hornblende rock; sometimes intermixed with green transparent talc; and sometimes passing into compact hornblende[i]. And again on another occasion he speaks of a rock intermediate to serpentine and hornblende[k].

CHAP. IX.

On Porphyry.

THOUGH a perfect porphyry may be defined to be a rock of an homogeneous base, more or less indurated and generally argillaceous in its character, containing imbedded and distinct crystals of some simple mineral, as felspar or hornblende;

[g] Jameson, vol. iii. p. 135. [h] Saussure, tom. iv. p. 182, 183.
[i] Saussure, tom. iv. p. 187. [k] Ibid. p. 457.

yet very frequently, I believe, these crystals have been formed in so confused a manner as rather to represent fragments and even rounded fragments: and thus many imperfect porphyries may have been mistaken for breccias. Saussure in noticing the sharp angles of some particles of felspar in porphyry, and the rounded angles of others, argues that the latter are equally the result of crystallization as the former[l].

As it does not seem yet well ascertained whether porphyry is a distinct formation, or only a modification of some other rock, I shall not attempt to say much on the subject. My own opinion is that it is not a distinct formation, notwithstanding its extensive occurrence in the Cordilleras; but that it sometimes occurs as a modification of, sometimes as a vein imbedded in, the substance of other rocks: and this opinion receives some confirmation, in the latter point at least, from the following statement. Mr. William Phillips says, that whatever is not granite or killas with the Cornish miner, is elvan. Elvans, he adds, are interspersed between the schist; and appear to be commonly compact felspar containing crystals of quartz and felspar[m]. I shall refer to the opinion above expressed respecting the occurrence of porphyry as a modification of another rock in the chapter on rock marl.

[l] Saussure, tom. v. p. 42. [m] Geol. Transact. vol. ii. p. 140.

CHAP. X.

On Slaty Rocks, or Schists.

THE term *schist* is merely descriptive of a peculiarity of structure; and in fact is applicable to rocks of very different characters. Thus if we examine the schists of a mountainous tract, we shall find that in some instances they consist almost entirely of mica, or felspar, or quartz, or hornblende, or of mixtures of two or more of these substances; that, in other instances, by the admixture of carbonate of lime in every possible proportion they on one side simply effervesce on the addition of an acid; on the other, they are nearly entirely soluble in it.

It has been usual to consider the various characters of schist as correlative with their age, or the order of their deposition; and gneiss, the structure of which is schistose being supposed to be immediately incumbent on, or next in age to granite, other schistose rocks have been arranged in the following succession; micaceous slate, roofing slate, hornblende slate, chlorite slate, and the transition slate, or grauwacke of Werner. This regularity of succession is, I believe, now questioned on authorities as high and as numerous as those by which it was at first asserted: and there appears upon further investigation to be so complete an intermixture of all the varieties above mentioned, that they must be considered as of cotemporaneous origin: at least however none can be said to be absolutely older than the rest.

It has been already shown that Saussure in several instances noticed a gradual *transition* even of granite itself into schist; and, which seems to be a point of considerable importance, he frequently found that these granitic schists would effervesce upon the addition of an acid[m]: with respect to which, without however entering into the question whether such schists are of chemical or mechanical origin, I would here by the way remark, that the admixture of calcareous carbonate by no means militates against the hypothesis of their chemical origin; for carbonate of lime in the form of crystals of calcareous spar is found together with crystals of quartz in the cavities of true granite[n]. Again it is said by Saussure, that *alternations* of granite and schist are of very frequent occurrence even in the central rocks of the central chains, not only in the Alps, but in other mountains[o]: and in describing beds of granite in schist he argues that they must be upon the whole of cotemporaneous formation; the original solvent perhaps having deposited different ingredients in different parts: so that during the stagnation of this original solvent true granite was formed; and then other ingredients being brought, various schistose rocks were formed[p].

It appears from the following extract that the transition slate and large grained gritstone of Werner alternate, or at least are in immediate contact

[m] Saussure, tom. ii. p. 228, and iv. 45, 172.
[n] Ibid. tom. iii. p. 181. and tom. vii. 84.
[o] Ibid. tom. iii. p. 99. [p] Ibid. p. 98.

with, the granitic schists of an Alpine tract. The lower part of the Col de Balme is a moderately grained grey granite; above which are rocks intermediate to gneiss and micaceous slate: higher up are beds of a grey and sometimes greenish slate containing a great quantity of rolled pebbles, some angular, and others rounded, varying from the size of sand to masses of six or seven inches in diameter. These beds have together a transverse thickness of six hundred feet, and are continued for more than a league in length: some of the individual beds are very thin, remarkably fine grained and micaceous, and entirely free from pebbles; others are of considerable thickness and filled with pebbles; and occasionally the latter are found imbedded in, and alternating with, the former[q].

Mr. Playfair also observes that large tracts, consisting of a schistose and much indurated sandstone in vertical strata, alternating with other schists, occur among many of the primitive mountains[r]; and that on every side of the Grampians breccias are interposed between the primary and secondary strata[s]. Saussure again observes with respect to those large or small grained gritstones, which in all parts of the world have been found interposed between what are usually called primitive and secondary strata, that they do not cut off those classes from each other; between which there is a mutual and insensible gradation[t]. And on another occasion, in speaking of some lenticular

[q] Saussure, tom. iii. p. 141, 142. [r] Playfair Illustr. p. 14.
[s] Playfair Illustr. p. 211. [t] Saussure, tom. ii. p. 373—375.

nodules of quartz, disseminated through micaceous schist, he says that with many other mineralogists he considers them as the effect of a confused crystallization: particularly if they have not that regularity in their external character which accompanies the true pebble[u].

Brongniart also, in a late publication on the geological history of the Cotentin, a peninsula on the coast of Britanny, observes, in speaking of a shining argillaceous slate of a greenish colour, that the laminæ gradually becoming more and more undulated, and traversed by veins of quartz, and penetrated with oval nodules of the same substance, it passes insensibly without any change in its structure, or in the degree of inclination of its strata, into a steatitic schist: and that this schist also contains numerous nodules of quartz, which being penetrated by the matter of the talc (a constituent of the schist) cannot be considered as rolled pebbles, but as nodules cotemporaneous in their formation with the rock itself[x]. In continuing the above account he says, that in the midst of, or immediately after, the schists just described, occurs a series of granitic and syenitic rocks of the following characters: 1. Crystallized syenite consisting essentially of lamellar felspar, hornblende, and quartz, the felspar often predominating. 2. A kind of porphyritic basalt. 3. Various kinds of trapp rocks, very hard and dense, and breaking into rhomboidal fragments: these rocks are sometimes of a bright black, and sometimes of a greenish

[u] Saussure, tom. vii. p. 39. [x] Brongniart, Cotentin, p. 10.

black colour, and pass into greenstone slate interspersed with iron pyrites. 4. Rocks of granulated quartz. 5. Argillaceous or roofing slate; hard, and of a greenish colour [x]. Brongniart adds that this syenitic formation is accompanied with a granite consisting of grey felspar, glassy quartz, and of silvery white mica and black mica equally mixed; sometimes containing acicular fasciculi of tourmaline, and veins of grey clinkstone [y].

Humboldt says, that the most ancient rock in the rich mining district of Guanaxuato is an argillaceous or roofing slate incumbent on the granitic rocks of the district of Zacatecas. It is of a greyish black colour, is often traversed by an infinity of small quartz veins; at great depths passes into talcose and chloritic slate; and contains thin seams highly charged with carbon. Beds of syenite, of hornblende slate, and true serpentine, have been found alternating with each other as subordinate beds in this slate: and he adds, that this remarkable alternation of syenite and serpentine is also found in the isle of Cuba; where the serpentine abounds in schillerspar [z]. In some places the argillaceous slate lies under syenite, many thousand thin beds of this syenite alternating with thin beds of transition greenstone, veins of those two substances mutually penetrating each other [a].

To the foregoing accounts of Brongniart and Humboldt I here subjoin, as equally illustrative of the present subject, an extract from a paper of

[x] Brongniart, Cotentin, p. 13, and 12.
[y] Ibid. p. 14.
[z] Humboldt, tom. iii. p. 383, 384.
[a] Ibid. p. 392.

M. Godon relative to the vicinity of Boston in America. The neighbourhood of Boston in America, with the exception of alluvial depositions, is primitive; and rocks consisting of hornblende, felspar, and epidote, mixed in various proportions, almost entirely prevail. The compound often contains magnetical pyrites; sometimes contains garnet and specular iron ore; and also, though rarely, tourmaline[b]. Among these rocks are found the following: 1. A red or brown porphyry, resembling the Egyptian, containing crystals of white felspar: the base of this, which is compact indurated felspar, M. Godon calls petrosilex. Sometimes the base is green. 2. Petrosilex, or indurated compact felspar, insensibly passing into laminated felspar, or into a round grained conglomerate. 3. A slate varying in colour from green to grey, brown, red-brown, and blackish. It passes into petrosilex and sometimes answers to Turkey hone-stone. N. B. A portion of this schist, when analyzed, yielded soda. 4. Grauwacke. This, by the inhabitants called plumb-pudding stone, is by far the most abundant and remarkable rock of this country. It consists of agglutinated nodules differing in size and colour: the most common of which are, 1. Nodules of opaque and differently coloured quartz; appearing occasionally to resemble compact felspar, but not possessing its fusibility: these nodules sometimes contain small crystals of felspar. 2. Nodules of differently coloured compact felspar and slate. 3. Nodules made up of white, or greyish, or reddish grains of

[b] Ann. du Mus. tom. xv. p. 455.

felspar; with particles of glassy quartz, of hornblende, and sometimes of epidote. 4. Nodules of compact felspar, containing small crystals of felspar, and also of quartz. The nodules vary in size from a foot in thickness till the rock passes into the state of a common grit: their figure is commonly elliptical or orbicular: and when angular the angles are rounded. M. Godon adds, "Although I have attentively examined this rock *in situ*, I have never perceived in it a distinct stratification. It passes into the other rocks which I have described often by insensible gradations. I have specimens which, within the compass of four inches, present different transitions into compact felspar, hornblende rock, &c." M. Godon from all circumstances is not inclined to consider these nodules as rolled pebbles: and concludes by observing, that as the rock in which they occur passes insensibly into the character of a decidedly crystalline rock, and is traversed by veins of crystallized hornblende and felspar, it must itself be considered as primitive.

As it appears that several of the rocks here described by M. Godon, as well as those referred to by Brongniart, Saussure, and Mr. Playfair in the preceding extracts, answer to the transition formation of Werner, and are of that class called by him grauwacke; it must be allowed that Werner's hypothesis of the origin of that rock is rendered very questionable, from a comparison of its history as given by Mr. Jameson, with the facts above stated. Mr. Jameson says of grauwacke, that it is the most important of the transition class,

and is the earliest rock in which mechanical depositions occur [c]: and he adds that the fragments occurring in grauwacke, which occasionally approach in magnitude to rolled masses, are sometimes quartz, sometimes a kind of indurated argillaceous slate, and sometimes flinty slate [d].

But it is a self-evident proposition that, according to Werner's theory, these mechanical depositions could only have been derived from preexisting rocks; and these rocks in Werner's system are the following; granite, gneiss, micaceous slate, argillaceous slate, primitive limestone, hornblende rocks, serpentine, porphyry, syenite, topaz rock, quartz rock, primitive flinty slate, primitive gypsum, and whitestone. With respect to Werner's hypothesis of the origin of grauwacke it has long appeared to me extraordinary that the supposed fragments, contained in it, should be of such a partial nature, that masses of granite for instance, and even of limestone and gypsum, should not be of more frequent occurrence; for the softness of the two latter substances can hardly be brought as a reason against their being found in it, because shells are often found delicately preserved in rocks of the same formation.

Then again, with respect to those nodules of quartz of such frequent occurrence in grauwacke, though where grauwacke occurs in the neighbourhood of true granite this circumstance may be explained on the ground of the easily perishable nature of the other constituent parts, mica and fel-

[c] Jameson, vol. iii. p. 149. [d] Ibid. p. 150.

spar; yet where such a circumstance occurs in the neighbourhood of true syenite, which contains little or no quartz, it seems inexplicable. And if it should be said that the quartz has been afforded in such instances by the topaz rock or the quartz rock it may be observed, that, according to Mr. Jameson, these occur in small quantity, and are of little extent when compared with the other formations[e]: they hardly then will serve to explain a fact of so very general and extensive occurrence. But I consider the former argument as the stronger of the two: for in a rock supposed to be derived from granite, slate, and other preexisting strata, the absence of fragments of granite, where fragments of slate and sometimes of soft slate abound, affords a most powerful argument against the supposed origin of such a rock. And in this opinion I appear to be supported by the following observation of Saussure on a somewhat similar occasion. He once thought that those low sandstone hills, which abound in the neighbourhood both of the north and south side of the lake of Geneva, originated from the *debris* of the Alps; for they consist usually of a quartzose sand, mixed with a little argill and small plates or scales of mica; and are covered over in every direction, even to near their summits, with blocks of granite and slate, and fragments of other Alpine rocks[f]: but subsequent observations shewing him that these sandstones contain none of those fragments in their interior, and indeed no extraneous bodies of any

[e] Jameson, vol. iii. p. 143.

[f] Saussure, tom. i. p. 55.

kind, he was convinced that the materials of these strata must have been derived from some other source[g].

Whether the arguments I have above used be considered as of validity or not, I have the satisfaction of knowing that, in my opinion of the chemical origin of many rocks of the transition class of Werner, I am supported by the highest authorities. To Saussure, and Brongniart, and M. Godon, I might add the names of many distinguished geologists of this country; but it will be sufficient to name Mr. Greenough, who I have strong reason to believe entertains that opinion, at least to a considerable extent.

It is not my intention here to make any remark on the hypothesis involved in the term transition, as applied to rocks supposed to have been formed during the passage of our globe from a chaotic to a habitable state: but with respect to the term itself M. Brongniart justly observes, that it has been generalized in a most confused manner, and extended beyond all bounds. "Thus, he says, Brochant has classed some of the granite of even the high Alps among transition rocks: and de Buch classes the gneiss between Martigny and St. Maurice with grauwacke. Raumer has referred to the transition class the granite and syenite of Saxony and the Hartz; and Charpentier considers the granite of the Pyrenees as of secondary formation. So that all that we can refer to primitive tracts of country are some granitic and porphyritic dis-

[g] Saussure, tom. ii. p. 126.

tricts; which having been imperfectly examined, are incompletely known [h]." And in another part of the same work he comes to a conclusion, which, the more our knowledge of the phenomena is extended the more we are likely to admit, that the terms *primitive*, *transition*, and *secondary* must now be banished from the nomenclature [i].

In speaking of the general character of schists the same observation may be made, as in the instance of granite. There is an endless variety in the proportions of the constituent parts and in the degree of hardness of rocks of this class. Among the schistose rocks of the Alps Saussure describes a compound of quartz and mica, in which there is an infinite variety in the proportions of the constituent parts: sometimes the mica is in such small quantity as only to be visible by exposing the surface of the laminæ of the schist to the sun; sometimes from the preponderance of the mica the schist crumbles between the fingers: and the same rock in different parts has alternating laminæ of almost pure quartz, and almost pure mica [k]. As an instance of the difference in the hardness of schist Mr. Phillips states, that, in the sinking of two shafts in Huel Alfred mine, not much exceeding the distance of fifty fathoms from each other, the pay to the miner was in one instance fifty-five pounds for each fathom, but in the other only five pounds [l].

[h] Brongniart, Cotentin, p. 23, 25.

[i] Ibid. p. 21.

[k] Saussure, tom. i. p. 157.

[l] Geol. Transact. vol. ii. p. 132.

In travelling across Dartmoor last summer with the Rev. W. Hony we found the following remarkable differences of character in the schist that skirts the north part of the moor near Crockernwell. From the state of a crumbling slate it insensibly acquired the character of a nodular ironstone composed of concentric laminæ, each lamina being internally of a dark brown colour, and externally of the colour of yellow ochre: sometimes it had all the external properties of soft white porcelain earth: in other instances it was in the state of soft black earth, but contained small perfectly white specks, which had almost a crystalline regularity of form, but were equally soft with the rest of the mass. These differences occurred within an area of a few square yards: and the evidence on the spot was sufficient to convince us that no new stratum was here interposed, but that all these different characters were owing to peculiar states of the same schist. It would be satisfactory however to have the opinion of others on the subject, and I therefore describe the spot as nearly as I can; but we came upon it by accident after having lost our way. I think it was near a village called Stone. The foregoing fact seems to correspond partially with one stated by Mr. Farey; who says, that in open fissures in the fourth or lowest limestone rock of Derbyshire, beautifully white china clay is sometimes found; and sometimes black earthy manganese [m].

There are some other points in the history of

[m] Farey, vol. i. p. 299.

schists which will be considered in the following chapter.

CHAP. XI.

On metalliferous compact Limestone.

FROM every source of information that I have had it in my power to consult it appears, that among the series of schists which have been above described are commonly found irregularly defined beds of limestone of the following general character. It is usually of an earthy and very compact texture. In colour it varies from black through every shade of brown and red and grey; and occasionally is nearly white. In other instances it has a clouded or mottled appearance; and sometimes appears in the form of a coarse breccia. Occasionally it is very curiously contorted; and often abounds in organic remains, of which the more common kinds are, various corallines, shells of the class of anomiæ, and remains of numerous species of encrinites. The belemnite and the cornu ammonis so common in the lias, Oolite, and green sand formations, scarcely if ever occur in the limestone now under consideration, in this country at least: though from the descriptions of Saussure and De Luc I think that the similar limestone of the continent often contains the latter of those fossils.

As many mountain districts in this island

abound in this kind of limestone it is by English geologists commonly denominated *mountain lime.* The marbles of Devonshire, of Derbyshire, and of South Wales are good instances of the limestone whose history I am now tracing: but they are only partial instances; for the variety in its character is endless. The following circumstance is particularly deserving of notice. Williams, in his Mineral Kingdom, says, that he has in many places seen the mountain lime swell out from two or three fathoms to more than one hundred fathoms in thickness [n]. The variety also in its relation to the adjacent strata is endless: and I am convinced that it insensibly graduates as well into some of the schists already described, as into the gritstones and trapp rocks by which it is often accompanied; though the proof of this opinion is not of a nature to be easily if at all made evident in writing. I shall presently state the ground of my opinion.

In the mean time, as it seems probable that this limestone and the rocks usually accompanying it answer generally to Werner's transition class, it will be convenient for the sake of comparison to ascertain as nearly as possible the real character of the rocks constituting that class. And though I do not subscribe to Werner's hypothesis of the relative age of the several rocks of this formation, any more than to the hypothesis which led to the use of the term transition as applied to all, I shall begin with the limestone; which is considered by Werner as the oldest member of the

[n] Williams, Mineral Kingdom, vol. i. p. 125.

series: of which Mr. Jameson says, that it is so *compact* as to have usually a splintery or flat conchoidal fracture: that it is well characterized by its *variegated colours* which are black, smoke-grey, bluish, greenish grey, and red: that it is very frequently traversed by small veins of calcareous spar, and contains petrifactions of marine animals as *corallites*, *encrinites*, &c. He adds that it frequently contains caves: and when occurring in *mountain masses* forms rough cliffs, immense mural precipices, and narrow and deep vallies[o].

The foregoing description is so applicable to many of the limestones of Derbyshire, Devonshire, Somersetshire, Wales, Cumberland, and Yorkshire, that, judging by that criterion alone, I should not hesitate to admit them into the transition class of Werner. And though Mr. Jameson adds that the transition limestone of Werner is not particularly metalliferous, whereas the limestones of Derbyshire, above referred to, and of other parts of England abound in metallic veins, this difference need create no difficulty; for it is analogous to what happens in almost every other formation. Humboldt, who has had a wide field of observation in this respect, says, that perhaps there is no rock of the older formations which is not metalliferous in some part of the world.

Brongniart in a recent publication describes Werner's transition limestone as of a blackish colour, adding, that it contains sparry laminæ of the same colour, and is intersected by veins of

[o] Jameson, vol. iii. p. 144, 145.

white calcareous spar and Galena[p]. To which description I may add, that the transition limestone, N°. 65, in the Freyberg collection of the geological society is tolerably compact, nearly of a black colour, and contains small black sparry facets of a circular form. These *sparry facets*, as also the *sparry laminæ* of Brongniart, will I presume be readily allowed to be the surfaces of transverse sections of the encrinus; which, according to Mr. Jameson, is one of the fossils of the transition limestone of Werner[q].

With respect to transition trapp, as Mr. Jameson allows the toadstones of Derbyshire to be of this class[r], and as those rocks are familiar to most geologists, I need not say more on that part of the subject. Mr. Jameson indeed doubts whether the limestone of Derbyshire is of the transition class; but allows the toadstones of Derbyshire to be of the same class with the limestones.

The grauwacke specimens in the Freyberg collection of the geological society are so exactly like specimens which I have seen from Cumberland, and the rocks of Cumberland, most of which are of grauwacke according to Jameson[s], correspond so closely with those of St. Bride's Bay in Pembrokeshire, that I need not hesitate to call that part of the coast a grauwacke district: but the country round St. David's consists principally of slates and gritstones of all characters: and though the encrinal limestone which is common in Cumberland is not

[p] Brongniart, Cotentin, p. 5.
[q] Jameson, vol. iii. p. 146.
[r] Jameson, vol. iii. p. 149.
[s] Ibid. p. 152.

found about St. David's; yet it occurs among similar strata at no great distance. The same difference occurs in grauwacke as in the limestone rocks of the transition class; for while in some parts of the world it is remarkably metalliferous, in other parts it is entirely barren of metallic ore.

I have stated my opinion above, that all the rocks of this class of Werner not only graduate into and alternate with each other, but also with those schists which border on or occur in a granitic district; and that opinion is supported by very high authority. Thus Dr. Mac Culloch asserts that the existence of genuine clay slate (a primitive rock of Werner) with well characterized grauwacke slate may be seen in all the slate counties of England, especially Cornwall[t]; and the same gentleman, in a paper on the geology of various parts of Scotland, describes more than one suite of rocks not very unlike the schists and gritstones of St. David's Pembrokeshire; some of which he says completely answer to Werner's definition of grauwacke, and some to his clay slate: and he adds that they also alternate without any order; a fine clay slate often coming in between two coarse grauwackes[u]. Dr. Mac Culloch even suspects it is not possible to draw any line between the classes of rocks to which grauwacke and micaceous schist belong[x]. And correspondently with the difficulty here implied it appears that the metalliferous rock of the Hartz forest, which by

[t] Geol. Tran. vol. ii. p. 443. [u] Ib. p. 442.
[x] Ib. p. 417.

Werner is called grauwacke, by De Luc is called schist[y].

The instances in which metalliferous limestone passes into or alternates with schists and gritstones are numerous. Brongniart, having described transition limestone, says that it is accompanied with argillaceous and roofing slate, forming low rounded hills in the vicinity of Cherbourg; the slate containing organic remains disposed in "empreintes flabelliformes." This slate contains beds of ferruginous gritstone, puddingstone, breccia, and granulated quartz, all passing into each other[z]. So that they must all be considered as of cotemporaneous formation: and the result (judging from their insensible transition into each other) of a confused crystallization[a]. Pallas met with a somewhat similar suite of rocks to that described above by Brongniart, in that part of the Altaïsch chain situated between the Obi and the Irtisch; among which were vertical strata of gritstone, contiguous to and conformable with schistose honestone: the strata of honestone were bounded by a blue and black pyritical clay, which graduated into the honestone schist: the clay itself was vertically stratified and metalliferous; but it contained organic remains "des corallines foliacées[b]."

The impressions above described are probably referable to the fossil called the hysterolite, which De Luc describes as occurring in nearly vertical schist in the vicinity of Coblentz[c]. And he adds

[y] Jameson, vol. iii. p. 152.
[z] Brongniart, Cotentin, p. 6.
[a] Brongniart, Cotentin, p. 7.
[b] Pallas, tom. iii. p. 395, 397.
[c] Lettres, tom. iv. p. 293, 294.

two facts which are worth mentioning from their coincidence with similar facts which I have observed in the schist of Dartmoor; and which the Rev. J. Conybeare has also observed in the neighbourhood of the same district. The organic remains contained in the schist near Coblentz are pulverulent, and the schist containing these remains are *not metalliferous:* there is however metalliferous schist in the neighbourhood; but it is remarkable that the metalliferous schist contains *no organic remains.*

Mr. Playfair observes, that the rocks about Plymouth consist of calcareous strata in the form either of marble or micaceous limestone alternating with varieties of the same schistus which prevails through Cornwall to the west, and extends eastward into Dartmoor, and on the sea-coast as far as Berry Head[d]: and he says also, that the strata of Ingleborough, and of some other metalliferous calcareous mountains in the west of Yorkshire, alternate with a very coarse grained sandstone[e].

The insensible transition of metalliferous limestone into schist is noticed by Dr. Mac Culloch also[f]. And Saussure says, that when you come upon the contorted calcareous strata of the Alps, these strata begin to alternate with and pass into schist; and that this observation has been generalized[g]. Saussure on another occasion marks a gradual transition from rocks purely calcareous to schist,

[d] Playfair, Illust. p. 165. [e] Ibid. 175.
[f] Geol. Transact. vol. ii. p. 415. [g] Saussure, tom. ii. p. 195.

by means of the mixed calcareo-argillaceous class [h].

De Luc frequently takes notice of the strange intermixture of the limestone and schist about Totness &c; and also of the capriciousness in the direction of the schistose strata [i]: and the same thing has been observed by others over a very great extent of that country [k].

Mr. Farey observes, that the black shale immediately under the lowest or mill-stone grit of Derbyshire contains accidental beds of micaceous sandstone, which are sometimes as coarse as the millstone grit; and also contains beds of dark blue or black limestone [l].

Dr. Berger says, that the solid strata of the metalliferous limestone of the Isle of Man have intervening and crumbling beds [m]; and this is a circumstance I have repeatedly observed in the limestones of Devonshire, Worcestershire, and South Wales. Thus the limestone incumbent on Malvern Hill, on the Herefordshire side towards Ledbury, which evidently belongs to the class now under consideration, is sometimes so charged with argillaceous matter as scarcely to effervesce on the addition of an acid.

The following short notice of part of an excursion into South Wales, which I made in the summer of 1811 with the Rev. W. Conybeare, will

[h] Saussure, tom. ii. p. 228.

[i] De Luc's Travels, vol. iii. p. 322.

[k] Ibid. vol. iii. p. 100.

[l] Farey, vol. i. p. 228, 229.

[m] Geological Transactions, vol. ii. p. 43.

not perhaps be unacceptable to some of my readers; and at all events is connected with the present subject.

There prevails between Ross and Monmouth a sandstone which sometimes contains white quartz pebbles, and sometimes is of a variegated red and bluish green colour: and near Monmouth we met with a stratum indistinctly made up of mountain lime and variegated sandstone. We met with a similar compound of limestone and sandstone, of a mixed red and green colour, near Ragland; and onwards nearly to Abergavenny. And in that amphitheatre of hills near Abergavenny in which Lantony Abbey stands, which principally consist of slaty sandstone, limestone occasionally occurs highly charged with argillaceous particles.

The mountain lime of the Blorenge, not far from Abergavenny, comes in among strata of a sandstone sometimes containing pebbles of quartz; and the nearer the lime is to the sandstone, the more it approaches in appearance to it, and the less it effervesces on the addition of an acid.

Between Abergavenny and Brecon, particularly as you approach Brecon, the sandstone becomes more slaty and micaceous. Now and then argillaceous mountain lime occurs, which has here and there an Oolitic character; and often contains encrinitic remains. In the same neighbourhood we met with an irregular breccia consisting of masses of limestone and sandstone. The Van near Brecon, the highest mountain of South Wales, appears to correspond with the grauwacke of Werner, and has the character of a slaty micaceous

red gritstone. It is divided into nearly horizontal beds not remarkably thick.

Limestone comes in between Brecon and the sixth milestone towards Landovery; and the accompanying slaty sandstone acquires a very green shade: but occasionally it is of a brick red colour, and appears as if it had been calcined, but is interspersed here and there with green streaks and patches: sometimes it resembles a brownish red toadstone, with cavities containing a dark coloured pulverulent substance. The foregoing characters of this sandstone continue on to Trecastle, and along the road to Langattock, over the hills, to a place called Pont-ar-Lleche; there, after a long and steep descent, we suddenly came upon a mountain stream which cuts its way through nearly vertical strata of what might be called a roofing slate[n]. Above the bridge, the upper front of which is covered with ivy, is a quarry which is evidently in a part of the rock forming the bed of the river. The strata in this quarry are nearly vertical, and from three or four to twelve or fourteen inches in thickness. Their character is very various; some being very like those at the top of the Van; some approaching in appearance to chert; others very like the red and greenish blue rock marl so common in Worcestershire, excepting that their colour is more dull: some so closely resemble fine gneiss or highly crystallized micaceous schist, that they might easily be mistaken for them,

[n] I have been very lately informed that the literal signification of Pont-ar-Lleche is "the bridge upon *slate*."

but that the occasional impressions of shells shew their connection with what are usually called more recent rocks. In some parts of this quarry the stone shewed the same disposition to break into irregular parallelepipeds, which is observable in many parts of the Van and the hills of this country in general.

After having quitted Pont-ar-Lleche, on our way towards Llandilo, we saw among the stones by the road side fragments of a species of a compact schist of a bluish black colour, and very tough and hard. In the course of a few miles we met with a quarry of a similar stone, the stratification of which was very imperfectly visible: and we thought it a variety of the rock forming the bed of the river at Pont-ar-Lleche. In continuing our road to Llandilo the same schist assumes different appearances, often passing into completely shivery shale of a ferruginous colour.

A little beyond Llandilo, in a quarry in Lord Dynevor's park, we found a bluish black coloured, slaty, argillaceous limestone; containing impressions of an *oniscus;* two or three varieties of anomiæ; and sometimes, though rarely, *pentacrinites;* also numerous veins of white calcareous spar, and occasional veins of quartz. In some parts this rock passes nearly into the state of the *rotten stone* of Derbyshire; and even those parts which most nearly approach to the state of pure limestone undergo a superficial alteration, which penetrates the substance to a greater or less extent, and changes the colour from a bluish black to a dull whitish grey.

From Llandilo to Caermarthen the strata which prevail are ferruginous shale and gritstone. Near Abergwili, about one or two miles to the east of Caermarthen, the shale becomes very compact and has some resemblance to bluish grey porcelain jasper with irregular streaks of a black colour. From Caermarthen to Ferry-side, at the mouth of the Towy, ferruginous shale, more or less compact, prevails the whole way. The cliffs at Ferry-side opposite Llanstephen-castle consist of alternate beds of gritstone, white puddingstone, and *red* and *bluish green* indurated marl, with occasional veins of calcareous spar: and it is particularly worth observing, that the red and green marl forms the *lower part* of the cliff.

I am very well aware that many whose judgment I respect will differ from me in some of the opinions expressed in this chapter, particularly in the opinion that the transition limestone of Werner answers to the mountain or metalliferous limestone of English geologists: and perhaps, had my opportunities of actual observation been more extensive, I should not have adopted these opinions. Every thing however, and the communications of others not less than what I have myself seen and read, convince me that it is very difficult, with every means of assistance, to make out a satisfactory statement of the mutual relation of the strata above mentioned.

CHAP. XII.

On the Rock Marl of English Geologists.

FEW if any of the formations are more distinctly characterized or more widely diffused than that I am about to consider. In this country it is often known in common language under the name of *red ground*, and forms that red soil so prevalent in Herefordshire, Worcestershire, Somersetshire, Devonshire, and other counties. It must however be observed by the way, that specks of a bluish green colour, sometimes of an irregular form and sometimes perfectly circular, occur in the midst of the red marl; and that sometimes entire beds of the rock marl are of that bluish green colour.

This formation appears to vary much in character; passing insensibly into fine and coarse grained gritstone; and perhaps into those schists and limestones and trapp rocks, which often accompany it; and at all events it may with great propriety be considered, in a practical sense at least, as the matrix or repository of gypsum, rock salt, and coal properly so called: and these subordinate formations are so involved in its history, that its presence may generally be inferred from their occurrence in any part of the world.

The existence of rock marl is frequently denoted, not only in this country but in numerous parts of the continent, by the names of places situated upon it, which are expressive of the red

colour or nature of the soil; as Redland, Marley, &c. So in America the Rio Colorado on the western side of the Cordilleras, and the Rio del Norte, called also the Rio Colorado, on the eastern side, appear to owe their colour to particles of rock marl washed away by their waters: for their colour is described as red, and the plains through which they flow are said by Humboldt to abound in common salt[o].

The following description from Pallas's Travels, which would at any time have struck me as applicable to the rock marl, presented itself to me in a manner peculiarly impressive from the coincidence in the state of the gypsum there described, with some of the gypsum of the rock marl near Sidmouth, which I had very recently had an opportunity of observing. On the banks of the Oka, at about seventy or eighty miles from its junction with the Volga, there is a hill composed of very solid red marl, resembling *burnt brick*. In this marl irregular masses of gypsum occur, and this gypsum is sometimes disposed in the form of veins crossing each other so as to present a *reticulated surface*; in which case the gypsum is usually *striated*, and forms as it were a frame-work or border to the cubiform pieces of marl which it incloses. Here and there is found in the same marl a species of amianthus or *fossile leather*; which is white as snow; and is so curiously rolled together that it might be mistaken for a heap of faded leaves; and from its appearance and pliability

[o] Humboldt, tom. i. p. 231. and tom. iii. p. 325.

may properly be compared to *paper* that has been torn [p].

It would be impossible for me to describe in more appropriate terms the appearance of the reticulated veins of striated gypsum, met with by the Rev. William Hony and myself last summer, in the red roek of the cliffs situated about half way between Sidmouth and Seaton in Devonshire; as also its occasional resemblance to fossile leather: but the occurrence of such a mineral in such a situation was so unexpected, that we were led to make some experiments on the substance resembling it, and soon found that it was nothing more than gypsum; nor was it difficult indeed to trace on the spot the gradual transition of the transparent crystalline gypsum into this amianthiform state. Pallas observes, with respect to the large beds of gypsum occurring in the red marl described by him, that they are not known to contain any organic remains [q]: and this observation applies, I believe, to the similar gypsum-beds of this country.

The following notices of foreign rock marl occur in different authors. De Luc observes, that that foliated sandy marl of a reddish colour interspersed with blue spots, which occurs near the Bristol passage, is found in various parts of the continent as well as of England [r]. The low sandstone hills which abound in the neighbourhood of the lake of Geneva appear evidently to be a form

[p] Pallas, tom. i. p. 60—63.

[q] Ibid. p. 85.

[r] De Luc's Travels, vol. ii. p. 232.

of the rock marl of England; for Saussure says, that they consist usually of a quartzose sand mixed with a little argill and small plates or scales of mica; that they contain no organic remains[s]; that coal is sometimes found between their strata; and that they contain silky gypsum in argillaceous beds[t]. The mineral waters of Courmayeur situated to the north-west of Aoste, in a valley bounded on the north-west by the central chain of the Alps, issue from a soil consisting of red ochry earth and gypsum[u].

Barrow in his account of China says, that the immense desert of sand, described in the native language by the term "sea of sand," which stretches along the north-west frontier of China, and divides it from Tartary, is many thousand feet above the level of the ocean; and that to the west of this plain of sand a group of mountains arises in Tartary, some of which are more than fifteen thousand feet above the level of the plain in which they stand: these mountains are of sandstone, and rest upon plains of sand mixed with rock salt and salt petre[x]. I have referred to this statement on account of the nature of the rocks, rather than on account of their elevation, respecting which there is probably some error; though Barrow says, that the measurement is given on the authority of M. Gerbillon, who was a tolerably good mathematician and had good instruments. In another part he

[s] Saussure, tom. i. p. 55, and tom. ii. p. 126.

[t] Ibid. tom. i. p. 55, 51.

[u] Ibid. tom. iv. p. 49.

[x] Barrow's China, p. 429.

says, that the coals of Peking are brought from the mountains of Tartary; which fact shews that the sandstone of those mountains belongs probably to the coal formation[y]. The red sand of the great desert of Persia is probably derived from rocks of the same formation; for there are metalliferous mountains producing galena in the neighbourhood[z].

The country between the Volga and the Oural or Jaik abounds in saline springs, and a red marly soil impregnated with salt; and some of the hills in this neighbourhood are described by Pallas as composed of strata of reddish clay, mixed sometimes with gravel and sometimes with rolled pebbles[a]. If these strata of reddish clay are mixed with real gravel and real pebbles, I should hesitate in pointing them out as the rock marl: but considering that even Saussure is supposed to have occasionally described soft gritstones as gravel, it is very probable that Pallas has here made the same mistake; especially as some states of the rock marl are not unlike a mixture of clay and gravel. Rocks of red sandstone, red marl, and gypsum, occur in that part of Russia in which the Don and the Volga approach most nearly to each other (about forty-eight N. Lat.[b]): and a branch of the Oural mountains, running parallel to the river of the same name, contains hills of gypsum, which is occasionally of a red colour, and rock salt; and Pallas says expressly, that no part of the

[y] Barrow's China, p. 551.
[z] Kinneir, p. 224.
[a] Pallas, tom. i. p. 331, 345.
[b] Pallas, tom. v. p. 350.

world is richer in salt than southern Russia, Siberia, and Tartary[c].

A circumstance in the history of the rock marl, which seems particularly deserving of attention, is its alternation with, and transition into, beds which would usually be called conglomerates. Thus the red cliffs at Budleigh Salterton near Teignmouth, which are of considerable height, and those also of Teignmouth itself, consist of alternations of argillaceous beds with beds of sandstone and of breccia[d]. And the red strata on the opposite side near Powderham are alternately soft and stony, but always intermixed more or less with strata of breccia; and they are inclined in various directions[e]. The quarry at Heavitree near Exeter answers in a great measure to the above description. And in various parts of Worcestershire I have again and again observed alternations of rock marl with small and large grained gritstones. Haldon hill is another similar instance: in which the insulated masses of a syenitic porphyry that frequently occur, I have no doubt are cotemporaneous concretions; both from the manner in which they are imbedded, and from their internal character: for they resemble no stratum in the neighbourhood; the prevailing colour of their mass is red; and most of the contained crystals of felspar, even the whitest, are more or less charged with a shade or even distinct specks of a red colour.

[c] Pallas, tom. i. p. 365, 374, and 420.

[d] De Luc's Travels, vol. iii. p. 75, 84.

[e] Ibid. p. 393.

In all the foregoing instances the regularity in the arrangement of these gritstones, even of the most confused, discountenances the idea of their having been deposited in the manner of gravel; for although a partial regularity is sometimes observable, there is no such general regularity in acknowledged gravel beds.

Descending into Newport in Glamorganshire from the east you have a shivery red stone intermediate in its character to schist and sandstone: on the opposite side of Newport you have the same kind of rock passing sometimes into indurated, stratified, red argillaceous marl, and sometimes into bluish green marl. From Pontypool to Usk, and onwards to Monmouth and Ross, are modifications of red sandstone. From Ross to Ledbury the red sandstone becomes more of a brecciated character than usual. Round Worcester it sometimes resembles mere marl, with occasional patches of a bluish green colour; sometimes a fine sandstone, and sometimes a breccia. Mr. Farey says, that the red marl when furrowed into vales and hills presents many bassets of micaceous gritstone beds of considerable thickness, which are sometimes so little connected as to be mere sand[f]. According to Dr. Holland, the marl beds, which form the most peculiar feature in what he calls the alluvial strata of the plain of Cheshire, occur in every part of the district; and are sometimes interposed between layers of sandstone containing large assemblages of fragments of older rocks. Por-

[f] Farey, vol. i. p. 148.

tions of granite, often of large size, and shewing on their surface evident marks of attrition, are among the most common appearances in these assemblages: but no granitic rocks are found within fifty or sixty miles of this district[g].

The red rock so prevalent about Exeter assumes a great variety of character between that place and Cullumpton. In some parts it is like a stratified gravel; in others like a compact sand: sometimes the seams are parallel and horizontal, sometimes inclined and curved in various ways; all within a small compass. Sometimes it becomes spongy in its texture, and contains cavities filled with a brown pulverulent powder; sometimes it resembles crumbling schist; or approaches the character of red marl, mixed however with bluish green spots.

The foregoing characters of the Devonshire rock marl appear to take place in a suite of rocks, on the shores of the gulph of Genoa, which belong to a branch of the Alps running north and south and terminating in the sea at Frejus, to the south-west of Nice. Thus according to Saussure the rocks in the neighbourhood of Frejus on the coast of Genoa resemble lava, and often have cavities filled with decayed ferruginous powder; and contain perfectly angular masses of porphyry: and in this neighbourhood is a cape called "Cape Roux" from the predominating colour of the neighbouring rocks[h]. From Antibes to beyond Frejus a violet coloured gritstone abounds, horizontally stratified

[g] Geological Transactions, vol. i. p. 40.

[h] Saussure, tom. v. p. 423, 424.

and often containing masses of porphyry and of other gritstones: and Saussure says of some of these gritstones, that if the cementing medium were more compact, they might easily pass for porphyry[i]. The same gritstones alternate sometimes with greenish argillaceous gritstones[k], and sometimes with beds of clay. Their unequal destruction, he adds, makes a very hilly road for the traveller[l]. I need not say that the last mentioned circumstance is characteristic of Devonshire. Sometimes in the red porphyry belonging to these gritstones the felspar, though whitish and opaque, is nevertheless brilliant[m]: and this circumstance is also characteristic of some of the porphyritic nodules of the red rock of Devonshire, particularly in the neighbourhood of Teignmouth.

Humboldt seems to describe rock marl &c. in the following passages. In North and South America, calcareous beds, resembling the Jura limestone (much of which is the metalliferous compact limestone), are covered occasionally with beds of indurated clay containing fibrous gypsum[n]. Again, speaking of a schist containing beds of syenite, he says it is sometimes covered by a breccia having an ochry argillaceous cement, containing angular fragments of quartz, porphyry, and syenite. Beds of this kind of breccia sometimes alternate with others in which grains of quartz are united by an ochry cement: and sometimes this cement becomes

[i] Saussure, tom. v. p. 440.
[k] Ibid. p. 442.
[l] Ibid. p. 436.
[m] Ibid. p. 437.
[n] Humboldt, tom. iii. p. 390.

so abundant as to constitute beds of mere clay, which alternate with a large grained breccia[o].

In many instances the rock marl appears to be distinctly stratified; and if organic remains occur in it, as has been stated by Mr. Townson, there is at once satisfactory evidence of an origin partially mechanical: but the reticulated disposition of the fibrous gypsum contained in it, and the perfectly arbitrary form of those blue specks and veins with which it is so frequently interspersed, are evidences of a chemical origin: and after all it must be allowed that it adds one to the number of those inexplicable associations of chemical and mechanical characters so prevalent throughout almost all the strata of the earth.

The geologists of England are not yet, I believe, unanimous in their opinion, to which of the formations of Werner the rock marl belongs; though there seems strong ground for believing that it belongs or even answers to his *old red sandstone.*

If, as will be readily allowed, it is characteristic of the rock marl to lie under the lias, to contain gypsum and rock salt, to be interspersed accidentally with specks and veins of a greenish blue colour, and to pass from the state of mere marl to a fine or even coarse-grained gritstone (all which points I have verified by repeated observation); then there can be no doubt that the strata round about and at Droitwich in Worcestershire must be considered as rock marl: and Mr. Horner consi-

[o] Humboldt, tom. iii. p. 388.

ders the sandstone strata, in which the brine springs of Droitwich originate, as of the same nature with those which Mr. Aikin has described as occurring to so great an extent in Shropshire and Staffordshire: and the strata in which the rock salt and brine springs of Cheshire are contained are of a similar nature [p].

But Mr. Aikin considers the sandstone of Shropshire and Staffordshire as the old red sandstone of Werner; which is thus identified, if Mr. Aikin's conjecture be true, with the rock marl of England. And the conjecture receives support from Mr. Jameson's statement, that Werner's old red sandstone is in great abundance in England; for the rock marl prevails in Devonshire, Somersetshire, Gloucestershire, and several other counties, both of England and of South Wales. Mr. Jameson also states that it contains cobalt: and cobalt has been found in the sandstone of Cheshire.

CHAP. XIII.

On Rock Salt.

As rock salt, and coal, and gypsum, have usually been found in the vicinity of rock marl, the presence of any one of the former is a presumption of the existence of the latter in the same neighbourhood, especially if that presumption is corroborated by other circumstantial evidence. Thus when it

[p] Geol. Transact. vol. ii. p. 95.

is known that rock salt is used as building stone at Ormuz[q]; and that the sand of the great desert of Persia is of a brick red colour; and that salt abounds throughout that desert; there can be very little doubt in the mind of a geologist that the rock marl formation abounds in that part of the world. The same formation probably abounds also about the streams of the Indus and the Ganges, after they have quitted the mountains; for it is observed by Major Rennell, that in the tract between the Indus and the Chelum are wonderfully productive salt mines, affording masses of salt hard enough to be formed into vessels, &c.[r]

In reading the lately published voyage of Captain Flinders it appeared probable to me, that rock salt and coal occur in more than one part of New Holland: but this is stated from a note made without any reference, though made soon after the perusal of that work.

According to Humboldt, rock salt and coal abound both in upper Louisiana, and in those extensive northern regions contained between Hudson's Bay and the stony mountains of Mackenzie[s].

I need not insist on the existence of rock salt in Africa; and though we have little satisfactory evidence of the formation to which it belongs, yet as syenitic rocks occur in Upper Egypt, and magnesian limestone in Lower Egypt, and Vitruvius

[q] Kinneir, p. 13. and Voyage of Nearchus, p. 322.

[r] Rennell's Hindostan, p. 69.

[s] Humboldt, tom. iv. p. 135.

mentions a spring of tar near Carthage[t]; we have good geological reasons for expecting that in those parts of Africa the rock marl may be found.

With respect to the formation to which the salt lakes of Siberia and of Mexico belong, I do not presume to offer an opinion; the circumstances attending them are so peculiar, and the analysis of the salt gives such different results from what is usual. I shall only observe with respect to the last point, that the composition of the rock salt of Europe is not always uniform. Thus the brine of Cheshire does not contain any sulphate of soda; while the brine of Droitwich contains nearly two per cent of that salt, which is also contained in many of the foreign brine springs[u]. Throughout the whole of the inhabited part of New Spain no considerable bed of rock salt occurs; it scarcely indeed is found in the state of a bed, but is principally disseminated in argillaceous soils, which cover the top of the Cordilleras: in which respect, Humboldt observes, Mexico resembles Thibet and Tartary. The following remarkable fact is stated respecting this native salt, namely, that after it has been separated from the soil by lixiviation, it appears to be renewed, like nitre, by contact of the atmosphere[x].

The salt lake of the valley of Mexico holds both muriate and carbonate of soda in solution to such an extent, that its specific gravity compared with

[t] Vitruvius, lib. viii. cap. 3.

[u] Geological Transactions, vol. ii. p. 108, 109.

[x] Humboldt, tom. iv. p. 135.

distilled water is as 1021 to 1000: which, though inferior to the average specific gravity of the ocean, which varies from 1026 to 1028, exceeds the specific gravity of the Baltic [y].

Pallas says, that there are numerous lakes in the south-west parts of Siberia, which are in some instances of fresh water; in others, of a mixture of muriate of soda and sulphate of soda: and it appears that these lakes undergo great changes both with respect to their extent and nature; some of the fresh water lakes becoming saline, and *vice versa*. He adds, that the soil of these parts is often impregnated with natron and sulphate of soda [z].

I am indebted to Mr. Buckland for the following notice from Townson's Hungary, which is particularly interesting from the unusual fact of the occurrence of vegetable and animal organic remains in rock marl. In the great salt mines of Wielicza in Gallicia, Mr. Townson obtained a specimen of marl containing two bivalve shells found at 36 fathoms depth, and a crab's claw at 40 fathoms; and a piece of charred coal mixed with salt and gypsum at 100 fathoms [a]. The section of these mines is as follows:

Vegetable soil	2	fathoms
A sandy kind of clay called leim (loam?)	5	
A very fine sand like tripoli effervescing with acid	$3\frac{1}{2}$	
Marl with sand mixed with loose stones	9	
Sandstone	1	
Marl mixed with salt in small patches and cubes	20	
	$40\frac{1}{2}$	fathoms

[y] Humboldt, tom. ii. p. 134. [z] Pallas, tom. iii. 23, 38.
[a] Townson's Hungary, p. 393.

On both sides of the Carpathians the country is stored with salt: on the south it begins at Eperies, and extends 4 or 500 miles eastward through Transylvania, in which tract Mr. Fictel enumerates 159 different places where rock salt or salt springs are found. On the north side also of the Carpathians it exists in great profusion; extending from Wielicza in Gallicia some way into Moldavia; in which range Mr. Fictel enumerates 58 places where rock salt or salt springs are found [b].

CHAP. XIV.

On Coal.

IT is stated by Mr. Jameson, that the true or *independent coal formation* of Werner answers to the principal coal fields of England: and the specimens of coal in the Freyburg collection of the Geological Society marked 81, 82, 83, very closely resemble the Staffordshire coal; for they contain bits of charcoal between the laminæ, and they are accompanied by a micaceous coal slate very like some of the English coal slates. Mr. Jameson adds, that Werner's independent coal formation is peculiarly characterized by a gritstone varying in the size of its particles, by a friable micaceous sandstone, and by slate clay; but that the position of this formation in regard to other stratified rocks is doubtful [c]. And correspondently with this

[b] Townson's Hungary, p. 394.

[c] Jameson, vol. ii. p. 178—181.

assertion it happens that some experienced geologists think all the coal fields of this island, for instance, connected with each other as to the number and order of their strata: others again, equally experienced, think that no two agree. Mr. Farey says, that the Dudley coal field is *above* the magnesian lime[d]: but that the Ashby-de-la-Zouch coal strata are *under* it[e]: and by some again it is asserted, that coal is always found *above* the mountain limestone; by others, that it is occasionally found *under* the same limestone.

Though I would not pretend to decide respecting that of which so many others are doubtful, I may be permitted to express my opinion, that the several branches of the coal formation are very intimately connected both with the rock marl and the transition schist of Werner. But it would be very difficult, if not impossible, to produce all the evidence on which this opinion rests; for it results from the accumulation of an infinity, practically speaking, of minute particulars; which, though of little consequence when taken individually, yet in the aggregate press with the force of conviction on the mind of the observer. The following facts either immediately or by probable consequence seem to justify the foregoing opinion.

Near Newport in Glamorganshire there appears to be an alternation of red and blue rock marl with transition schist: and between Newport and Pontypool, passing by Abercarne, you find your-

[d] Farey, vol. i. p. 174. [e] Ibid.

self among a group of hills, that might almost be called mountains, which are the repository of the coal of that district. The prevailing character of the strata of these hills is a species of sandstone, which is occasionally disposed to disintegrate concentrically: sometimes it is separable into thin and very regular laminæ, the surfaces of which are micaceous: sometimes it is disposed to break into rhomboids, or moulders away like some varieties of the whinstone of Scotland, which it occasionally closely resembles in external character. At other times it assumes the character of soft sandy schist, or resembles primitive slate of a brownish black colour. Among these hills I met with a limestone rock of a dark brown colour, having crystalline facets (probably sections of the encrinite), and containing also bivalve shells; in these respects evidently answering to the transition limestone of Werner. And as Mr. Williams says, that, though rarely, he has seen *lead* and *copper ore* in some of the slips of a coal field[f]; it hence becomes still more probable that the coal strata are connected with the metalliferous limestone &c.

Forster on coal strata says, that the great red freestone which lies under the coal measures contains near its bottom a bed of gypsum[g]; which shews a probable connection between the coal strata and the rock marl.

Among those rocks near Frejus, which have been already described, there occur coal mines, and a red porphyry containing whitish red felspar and

[f] Williams, Mineral Kingdom, vol. i. p. 338. [g] P. 44.

colourless transparent quartz; and this porphyry closely corresponds in description with the concretions of porphyry in the red rock near Exeter [h].

Again, Humboldt says, that coal which is of very rare occurrence throughout the Cordilleras is found in the valley of Bogota, in the neighbourhood of rock salt [i]. The country round the Viloui, near its junction with the Lena, which is not above three degrees from the arctic circle, is a mountainous tract consisting of horizontal strata of limestone and sandy schist. Fragments of coal are found in the alluvial land of the river; and gypsum and rock salt occur in the neighbourhood. Pallas observes of one of the adjacent mountains, that, though sandy, it contains beds of millstone grit [k].

Sandstone and coal occur also in the northern part of the province of Canton, and in the adjoining province of Kiangsee; and the substratum of the low part is a clay of a dark red or brown colour: the mountains are chiefly of red sandstone; and the soil of the hills is a brown loam mixed with particles of mica [l].

As petroleum has an evident relation to coal, the presence of this substance in the vicinity of red marl is in part a confirmation of the truth of the opinion above expressed [m]. Col. Symes then says, that in ascending the great river of Ava he arrived

[h] Saussure, tom. v. p. 422.

[i] Humboldt, tom. iv. p. 134.

[k] Pallas, tom. iv. p. 133.

[l] Barrow's China, p. 594 and 543

[m] P. 114. supra, l. 24. &c.

at a creek called in the native language Petroleum creek; adjoining to which are springs of petroleum, from whence not only the neighbouring country, but many parts of India are supplied. The clay in the vicinity of these springs had the appearance of red ochre [n].

In a description of a coal field of the Mendip Hills in an early volume of the Philosophical Transactions, it is stated, that the surface in the neighbourhood is mostly a red soil which degenerates into malm, or loam, and often yields a rock of red firestone [o]; and Mr. Farey says, that there are accidental beds of highly micaceous gritstone in the rock marl [p].

There is at present a prevailing opinion, which receives great weight from the authority of Mr. Williams, whose experience has been very extensive, that coal fields are but limited patches, the extent and boundaries of which may generally be traced out and ascertained: and that they were originally flat bason-shaped vallies; the coal on all sides slightly dipping towards the centre [q]. And the foregoing opinion seems justified by what is stated by him in another part of his work, namely, that not only the beds of coal, but the intermediate strata accompanying them, gradually become thinner as they approach the boundary of the coal country [r]. According to the above descrip-

[n] Symes's Ava, p. 261.

[o] Philosophical Transactions, 1717. p. 968.

[p] Farey, vol. i. p. 466.

[q] Williams, Mineral Kingdom, vol. i. p. 130.

[r] Ibid. vol. i. p. 61.

tion, taken simply, there is no obstacle to the supposition that each of the strata of coal or of the accompanying beds are continuous throughout their whole extent: but it is well known, even to many who never thought of geology systematically, that the miner in a coal field is continually meeting with interruptions to his work in consequence of the presence of cross courses or *faults*; which not only cut through several of the contiguous strata, but alter the plane and direction of the divided parts; throwing the strata to a higher level on one side than on the other.

Respecting the coal measures generally, Williams observes, that thick and thin seams of coal occur without any progressive order, either from above downwards, or from below upwards: and the accompanying earthy measures have no more order in any point than the coals: so that twenty different seams of coal shall have each a superincumbent stratum different from all the rest [s].

In Forster's treatise on coal strata, which seems to have been principally compiled from Williams, though his sections, I understand, are original, it appears that the coal strata of the north of England, the aggregate thickness of which is from 500 to 600 fathoms, consist of

Beds of coal	30
——— clay, sometimes slaty, sometimes bituminous	85
——— grit, or else whinstone	70
——— limestone	20
——— ironstone	1

[s] Williams, Mineral Kingdom, vol. i. p. 63, 65.

Of the 30 coal beds, 24 occur within the first 180 fathoms: the 25th bed occurs immediately under the first limestone at 250 fathoms. The thickest coal bed scarcely exceeds 6 feet: but the average thickness is scarcely $1\frac{1}{2}$ foot. Of the 20 limestone beds, 19 are contained in the lower half of the series. The argillaceous and siliceous beds are interspersed pretty regularly throughout the series; but, like the limestone beds, vary very considerably in thickness.

Mr. Farey, whose general statement of the coal strata of Derbyshire and some of the adjacent counties agrees in many points with the preceding statement of Forster, says, that the coal strata of the great coal field of Derbyshire, Nottinghamshire, and Yorkshire, consist of numerous alternations of coal, argillaceous strata called *shale, bind &c.*, containing vegetable impressions; and of at least 20 gritstone rocks. He says of the argillaceous beds, that they are sometimes in the state of black chalk; sometimes in the state of potter's clay, and even of pipe clay[t]. He adds, that the fourth from the lowermost of the gritstone rocks is used for foot-paving in London, under the name of Yorkshire paving; being so called in consequence of its coming from Halifax. The lowest of the grits is commonly known by the name of the millstone grit: and under this lies the black shale of Derbyshire[u]. He adds, that the coal grits occasionally have no more consistence than loose sand; yet in the coal measures of Derbyshire there is no stratum of true sand[x].

[t] Farey, vol. i. p. 219.

[u] Ibid. p. 161, 175.

[x] Ibid. p. 462.

Mica, he says, prevails in almost all the gritstones, and in many of the shales of the coal measures; and in the lowest, or millstone grit, cavities occur, from six inches to three feet in diameter, filled with a mass nearly entirely composed of thin plates of mica: these masses are hard at first, but soon crumble on exposure[y]. Mr. Farey concludes by observing, that both in Derbyshire and Yorkshire the fourth gritstone from the bottom is fit for paving; which, united with many other points of resemblance, seems to shew, that the true coal formations are not so independent of each other as Werner supposes. Yet Mr. Williams says, that in any two coal fields that are far distant from each other, especially if a chain of hills intervene, there never are found the same class of coals and coal gritstones, &c.[z].

Faujas mentions a singular circumstance respecting some varieties of millstone grit. In speaking of the grinding stones employed in the polishing of agates at Oberstein near Mentz, (which country seems to correspond geologically with parts of Derbyshire,) he says, that they are made of a very hard reddish coloured sandstone, and are usually as much as a foot in thickness and six feet in diameter: but it sometimes happens that after these grinding stones have been used about a fortnight, they suddenly burst into pieces with a violent explosion. Faujas adds, that the

[y] Farey, vol. i. p. 466.

[z] Williams, Mineral Kingdom, vol. i .p. 121.

same circumstance has been observed in other grind-stones [a].

If we attempt to explain the origin of coal and its accompanying beds from internal evidence, we shall find many difficulties, which would hardly have been anticipated by previous reasoning. After the mind has been convinced, for instance, and this conviction is often reluctantly extorted, that coal is of vegetable origin, the first hypothesis which naturally suggests itself as to the mode of its formation is this; that powerful floods have swept away forests, and subsequently covered them with the ruins of the soil in which they grew; whence those beds of clay and gritstone which so generally accompany the coal itself. But Mr. Ray observed more than a century since, that there are no remains of trees, or even of shrubs, in the coal strata: and Mr. Jameson says, that the coal formation principally contains plants of marshy and woody places; arborescent ferns, and gigantic reeds; perhaps also palms [b]: and Mr. Buckland, who has already enjoyed an extensive field of observation, has never seen any thing in coal or the coal strata, that could be decidedly called wood or timber. Then again, though many of the vegetable impressions of coal are commonly described as species of fern; yet to whatever tribe of plants they belong, it appears, that, though upon the whole referable to a tropical climate,

[a] Ann. du Mus. tom. vi. p. 70.

[b] Jameson, vol. iii. p. 181.

very few, if any, correspond with known existing species [c].

Again, what must have been the mechanical force of those floods, which swept away and deposited not only such an enormous quantity of vegetable matter, but also that still greater quantity of earthy matter which constitutes the shales and gritstones of every coal field? or what must have been the degree of the attrition which reduced the preexisting strata to that minute state of division observable in the particles of those shales and gritstones? But Mr. Farey observes, what I have myself also again and again observed, that the particles of the coal grits are not rounded; so that they do not seem to have been subjected to attrition [d].

By what analogy again shall we account for the absence of calcareous matter from the generality of the shales and grits; or for the presence of pure calcareous beds interposed between them? Suppose, for instance, for a moment, that a great flood were now to overwhelm any known extensive tract of country; and that, in tearing up and depositing whole forests, it should subsequently cover them with beds of earth; on what principle could we expect that these should periodically be nearly entirely argillaceous, or siliceous, or calcareous? for where is there any extensive tract of country in which the components of all these natural forms of the strata are not present; and by what mode of action could the desolating violence of a flood

[c] Ann. du Mus. tom. v. p. 469. [d] Farey, vol. i. p. 442.

select one in preference to another? But the difficulties of this inquiry are not yet exhausted. How, for instance, shall we account for the extraordinary fact of numerous successions of coal alternating with earthy strata? for, let us grant that a flood shall have torn up and deposited the forests that were opposed to its action; and let us further grant, that the ravage of the waters continuing, the soil on which those forests grew shall have been subsequently washed away, and deposited upon the stratified vegetable matter; yet how are we to account for the *alternation* of these beds of coal and earthy matter? Vegetation cannot take place again till the waters have subsided; and, if we grant that a second flood shall renew the former process, by what inconceivable law shall the blind fury of such an agent deposit a second series of beds exactly on the same spot where the first series was deposited?

There are many of the phenomena connected with the faults of a coal field which seem incapable of any satisfactory explanation. Thus a bed of coal is sometimes found thicker on one side of a fault than on the other; which, on the supposition that the fault has been mechanically interposed since the deposition of the coal strata, seems inexplicable[e]. But the substance of the faults, though often hard, is sometimes mere clay or sand; and this fact seems to militate against the supposition of their having been mechanically forced through the strata[f]. Martin, in his account of the mineral

[e] Williams, Mineral Kingdom, vol. i. p. 59. [f] Ib. vol. i. p. 34.

bason of South Wales, observes, that though there are frequent faults in that coal district; and though these faults take ranges through the interior of the bason, and often throw the whole of the strata, for hundreds of acres together, from 40 to 100 fathoms up or down; yet still there is rarely any appearance on the surface that indicates a disjunction of the strata beneath: so far from it, that the greatest faults often lie under the most even surfaces [s].

However, one point at least, the final cause of the existence of these faults, seems certain; since, were it not for them, the coal strata, in consequence of their natural dip, would soon sink to such a depth, as would effectually impede the operations of mining: whereas now many of the separate portions of each bed are thrown up towards the surface, and thus brought within human reach.

CHAP. XV.

General Remarks on the Division of the Strata adopted in this Volume.

IN comparing the strata which are found in this island, to the north-west of the boundary line originally described, with those occurring on the south-east of the same line, there are some points which of themselves are sufficiently striking to

[s] Philos. Transact. 1806, p. 343.

justify the division I have adopted. In the latter, for instance, I believe there never has been found any form of the hard blue roofing slate, so common in the former. The same observation holds with respect to true coal and rock salt; both of which are of very frequent occurrence in the former, while neither of them has been found in the latter. Lastly, none of the strata characteristic of the south-east division, either in this or any other part of the world, has yet been found to be intersected by a metallic vein: with the exception indeed of pyrites, and oxide of iron or of manganese (and even these occur in very insignificant proportion) no metallic ore of any kind has been met with in them; whereas there is not one of the strata characteristic of the north-west division, which in some part of the world does not abound in metallic veins of various kinds.

In reviewing the history of the strata described in the ten preceding chapters it seems evident, to me at least, that their apparently arbitrary intermixture and general character is such as to preclude the possibility of framing any rational hypothesis as to their origin: and certainly there is no natural process in existence, capable of producing any of the commonest phenomena by which they are particularly characterized. Where, for instance, do we now see the formation of granite, or syenite, or porphyry, &c? where do we see the production of metallic veins, or of beds of rock salt, or even of genuine coal? On the truth of these positions I need not insist, since they are not likely to be disputed by even the

most cursory observer: but as I may possibly be thought to have confounded the true arrangement of many of the strata above described, I beg leave to offer a few remarks on that point.

In the preceding chapters I have attempted to shew, that the frequent alternations and mutual transitions, observable in the strata below the rock marl, are such as effectually to prevent a distinct classification of them: and I believe that even the rock marl not only appears under the varying form of mere clay, and fine and coarse grained gritstone, but that it sometimes assumes the character of a more or less perfectly defined porphyry and amygdaloid; and even insensibly passes into any of the rocks from granite downwards, and alternates with many of them. But in saying this I do not mean to advance the indolent and unphilosophical proposition, that, because any rock may insensibly be traced into almost any other, (a fact however which those who have seen most will be most ready to allow,) there is therefore no difference between them: nor do I deny that this change of character appears to be connected with some law, which in a general point of view has assigned its place to each series of rocks: so that in a geographical distribution, allowance being made for partial deviations, you pass from granite, mixed with hornblende rocks of various descriptions, upon that mixed class of slates and gritstones so very generally found contiguous to a granitic district; and among the last mentioned you find interspersed the mountain lime and coal series; the whole being bounded by the rock marl formation, with

its accompanying rock salt and gypsum. All that I maintain is this, that since the succession of the formations above the rock marl is usually to be traced with much ease, and can be satisfactorily demonstrated to an indifferent spectator, the same succession in the formations below the rock marl ought also by analogy, if it exist, to be visible and demonstrable; and if not thus demonstrable, it is in some degree probable, that there is no such succession. But if in addition to this it can be shewn, which is I believe the case, that the rock marl can insensibly be traced into the state of mountain lime or schist, or gritstone; and that these latter can also insensibly be traced into granite, and syenite, and the various forms of hornblende rock; and, lastly, if all these rocks are found occasionally to alternate with each other, (and, if I am not misinformed, coal has been found under mountain lime, and mountain lime under even granite,) from all these facts I think it necessarily follows, that there is a connection between these rocks, which, if it does not justify us in classing them under one series, effectually prevents us from finding any fixed law of their succession.

I am happy in being able to add the following powerful authorities in support of the opinion above expressed. Dr. Mac Culloch, in speaking of the usual division of rocks into primary, transition, and flœtz, is inclined to think that these are distinctions which are more easily made in the closet than in the field; and argues, that different strata which alternate must be collectively consi-

dered as of cotemporaneous formation [h]. Brongniart, in his account of the Cotentin, to which I have already referred, after having observed that granite and gneiss occur in a syenitic formation to the east of the Erzegebürge, and that this syenite overlies argillaceous schist, and even grauwacke; that Haussman and Von Buch found in Norway zoophytic limestone under a formation consisting of syenite, granite, porphyry, gritstone, and argillaceous schist; and lastly, that there seem to be very few granitic districts which can be referred to a primitive formation of granite, concludes by saying, that at present there is a great difficulty in establishing a good division of the strata [i].

Saussure again observes, that the mountains of St. Bernard are a mixture of various strata, which have hitherto been ranged in different orders: but that the complete intermixture of these different orders, particularly of slates with quartz rocks, appears to perfect the proof of what he has often suggested, that philosophers have been too hasty in classing different orders of mountains, and of establishing precise limits between primitive and secondary strata. It appears evident, he adds, that nature has not assumed those divisions for the rule of her operations; and that, if she has not made mountains of granite, strictly so called, incumbent on calcareous foundations, she has at least frequently mixed calcareous rocks and argillaceous schists with quartzose and micaceous

[h] Geological Transactions, vol. ii. p. 410.

[i] Cotentin, p. 25.

schists[k]: and in closing his account of the rocks of Mont Blanc, he says, it cannot be too often repeated, that we may expect to find, and do actually find in the mineral kingdom, all kinds of mixtures in all kinds of proportions: whence arises an infinity of mixed and indeterminate species[l].

I have not hitherto ventured much into the region of theory, and I am well aware of the caution that is necessary in treading on that ground: but as the following supposition respecting the origin of the crystalline strata is in part countenanced by the opinions of Saussure, I have less hesitation in proposing it. It may be asserted then, reasoning from the present state of our knowledge, that the crystalline strata must either have been deposited from some medium containing their elementary parts in solution; or they must have been formed by the mere command of the Deity. The possibility of the latter supposition is as easily admitted as of the former; but the mode of formation cannot be so intelligibly expressed in the one as in the other. For this reason, I prefer the supposition of some universal medium, from which the elementary parts of the strata in question have been formed or brought together: and since an endless variety is observable in the proportions of the constituent parts of granite, for instance, and of the simple minerals, as tourmaline, hornblende, garnet, &c. occasionally contained in it; since also there is an insensible transition from most highly

[k] Saussure, tom. iv. p. 264, 265.

[l] Ibid. p. 469.

crystallized granite, through various obscurely crystallized compounds of the same ingredients, till it passes into the finest schist; since again by a more or less tranquil state of the medium there would be a more or less perfectly crystalline deposition of the particles, and that in an agitated state of the medium not only would crystalline depositions approach in their character to masses mechanically aggregated, but would here and there be actually altered in their form by mutual attrition: since, lastly, rocks of apparently a mechanical structure are inclosed among rocks allowed universally to be of chemical origin: on these grounds taken collectively I believe, that all the rocks of the Wernerian classification from granite to the red sandstone (which, I think, has been shewn to correspond with the rock marl of English Geologists) are, however obscurely, in some measure connected.

As I have already said, I do not here suppose either that no distinction is to be made between these several rocks, or that they do not observe some general law with respect to their absolute and relative position. All that I mean to advance is, that by the varying operation of some law, the nature of which we have not the means of ascertaining, the same elements produced compounds of a different character in different parts of the same medium. And correspondently with this opinion Daubuisson says, that in two nearly contiguous parts of basalt, one part shall be almost of an earthy softness, the other as hard as any

rock[l]: and he says again, in describing greenstone, that it is a rock of granitic structure, composed of particles of laminated hornblende and felspar: and on another occasion he says, that in the same specimen one part will be sometimes compact basalt, another part highly crystallized greenstone, and the transition sometimes insensible, sometimes abrupt[m].

If it be maintained that the presence of organic remains is a proof of the mechanical origin of the rocks in which they occur, I can only say that these remains do often occur in rocks which but for their presence would unquestionably be admitted by every one to be most highly crystalline. Such is the rock of Tintagel in Cornwall, a specimen of which bearing the impression of shells was deposited in the Ashmole Museum by the Rev. J. Conybeare. Still more decidedly of a crystalline, and highly crystalline character, is the rock of Pont-ar-Lleche, above described; a specimen of which so struck Mr. Playfair and the late President of the Geological Society, that they immediately noted down the place from whence it came. The mass of the rock consists of a close aggregation of minute crystalline scales of mica, and would undoubtedly be called by many a highly crystallized micaceous schist; but in particular parts it is almost entirely made up of a congeries of the casts of small shells; the substance of which however is no less an aggregation of micaceous

[l] Daubuisson, p. 21. [m] Ibid. p. 123, and 60.

particles than is the general substance of the rock itself. Of an equally equivocal character is a specimen belonging to the East India Company, which came, as I understand, from Ceylon. It consists of a mass of shells, and of casts of shells, cemented together by a paste of a green colour, containing particles of semitransparent quartz and small crystals of reddish white felspar. In this specimen the substance of such of the shells as remain is calcareous and of the usual laminated structure: the rest of the stone very closely resembles one of those greenstones of Cumberland, and countries of that description, which are of a mixed chemical and mechanical character.

CHAP. XVI.

On the natural Arrangement of Chains or Groups of Mountains.

I PROPOSE in the present chapter to enquire into the natural arrangement of those groups or chains of mountains by which the surface of the globe is every where intersected; and as my own opportunities of actual observation have been limited and transient, I naturally feel some hesitation in questioning the statement of those who have had both a wider field of observation, and more frequent leisure for its cultivation. Nor should I take this step on the authority of my own experience; but from all that I have heard and read, I

feel convinced that there is not that degree of regularity in the natural arrangement of mountains which is supposed by many geologists; and which has been particularly pointed out by Werner.

To begin with the Alps, which are not only the most remarkable assemblage of mountains in Europe, but have been examined and described more accurately than any other, it does not appear either from the maps of Weiss, or from the observations of Saussure, that there is any thing like that regularity of parallelism in the vallies of those mountains, which one is led to expect from the general theory of Werner, nor any thing like that regularity in the succession of the strata pointed out by the same theory. So far from it, that after the lapse of many years spent in a most laborious examination of them, with every assistance and every qualification necessary for the purpose, Saussure came to this conclusion; that there is nothing constant either in the order, character, direction, or degree of inclination, of the strata composing that majestic assemblage of mountains: nothing, in short, constant in them but their variety [n]. On another occasion also he confesses that in viewing the group placed beneath his eyes from one of the highest summits near St. Gothard, the direction of the vallies did not appear to have any constant correspondence with the bearings of the strata; being sometimes placed parallel with, and sometimes at an oblique or even a right angle to them [o]. Again, he observes of the primitive mountains of Italy, Swit-

[n] Saussure, tom. viii. p. 241. [o] Ibid. tom. vii. p. 51.

zerland, and Savoy, that though at a great distance they appear to have that regular arrangement which has given rise to the term *chain*; yet this is a false impression, which vanishes upon a closer inspection[p]: and in another volume he asserts, that the chains of the Apennines near Genoa have no regularity either in their own direction, or in the direction of their accompanying vallies[q]. The immediate group of Mont Blanc, the Aiguilles of Chamouni, and the group which is to the south-west of Mont Blanc, are not at all connected with each other[r]: and Mont Blanc itself, though the highest summit of the Alps, is not in the centre of the mass of primitive mountains which surround it: for on the side of Italy there are many more high summits than on the side of Savoy; so that Mont Blanc is nearly on an extreme border of this mass of primitive mountains[s].

Mont Rosa, which is situated at the upper extremity of the Vallais, and appears to have been so named from the circular arrangement of its numerous peaks, disposed somewhat in the manner of the leaves of a rose, has an arrangement unlike all the elevated summits Saussure had ever seen: for such elevated summits usually are insulated like Etna, or ranged in right lines as Mont Blanc and its collateral peaks. Mont Rosa, on the contrary, composed of an uninterrupted suite of nearly equal peaks, forms a vast circus, which incloses within its area several hamlets, numerous

[p] Saussure, tom. vii. p. 290.
[q] Ibid. tom. v. p, 249.
[r] Ibid. tom. vii. p. 292.
[s] Ibid. tom. vii. p. 300.

pastures, and glaciers bordering on those pastures, and steep acclivities, which are continued to the very summits of these stupendous peaks[t]. The foregoing description corresponds partially with the description of the valley of Mexico. This valley, which is about 18 leagues in length and about 12 in breadth, is situated on the summit of porphyritic and amygdaloid basaltic rocks, surrounded by a circular crest of mountains 67 leagues in circumference[u].

In comparing the Alps on the Italian or Piedmontese side with those on the side of Savoy, Switzerland, and Dauphiny, there are great differences observable both with respect to the height and nature of the mountains. On the side of Piedmont they terminate more abruptly; forming a wall, as it were, and rising suddenly from the termination of the plain of Piedmont[x]. Nor does this appear to be, entirely at least, the effect of an actual removal of a part of the group; since even in the case of Mont Blanc, which is flanked by exterior chains on the side of Italy, and protected therefore from the action of any removing cause in that direction, the escarpments are much more abrupt on that side than in any other direction[y].

The nature of the strata is often as capricious as their arrangement: thus the most elevated and central parts of the chain of Mont Cenis are calcareo-micaceous schists; while granite forms the secondary ridges: and the central and highest

[t] Saussure, tom. viii. p. 54.
[u] Humboldt, tom. ii. p. 106.
[x] Saussure, tom. v. p. 170.
[y] Saussure, tom. v. p. 173.

rocks are nearly horizontal in their stratification, while the exterior ridges are nearly vertical [z]. On the south-east side of the Alps the granite descends nearly into the plain, and there are scarcely any calcareous strata till you approach Genoa or Venice; and there is serpentine in abundance: but the converse of this holds on the north-west side: and Saussure adds, that Pallas has also noticed in Russia and Siberia a marked difference between opposite sides of the same chain [a]. The opposite sides of the chain which the passage of the Simplon traverses are very different: the northern side, looking to the Vallais, consists almost entirely of vertical beds of micaceous limestone: the southern side, looking to Italy, consists of quartzose micaceous schist, of gneiss, and of a schistose granite, in strata either horizontal or inclined at an angle not greater than from thirty to forty [b].

Sometimes the two opposite sides of even the same mountain will materially differ. Thus from the north-west side of Mont Buet you descend on nothing but limestone; on the south-east occur an astonishing variety of rocks, partly consisting of gritstone, partly schistose, and partly granitic [c]. In descending from the summit of the Col de Balme either towards Chamouni or Martigny, you meet with granite, schist &c.: but in descending towards Valorsine a suite of very different rocks occurs, particularly of large grained gritstones [d].

[z] Saussure, tom. v. p. 174.
[a] Ibid. tom. iv. p. 215, 216.
[b] Ibid. tom. viii. p. 29.
[c] Ibid. tom. iii. p. 137.
[d] Ibid. tom. iii. p. 137.

Lastly, Saussure observes, that the intermixture of primitive with secondary, and of secondary with primitive mountains, so often observable in the Alps, should make us very cautious in admitting the hypothesis of a regular and progressive deposition of schist on granite, limestone on schist, and sandstone on limestone [e]. Thus even at the foot of the central chain of the Alps, where Mont Blanc &c. descend into the valley of Chamouni, there are secondary rocks both of limestone and schist [f].

De Luc also bears testimony to the variety of rocks occurring in the upper parts of Mont Blanc. The parts of Mont Blanc, he says, which are not enveloped in snow, wear away by the action of the weather; and the separated fragments falling on the glaciers descend with them, and accumulate at their edges in those mural heaps called *moraines*. One of these moraines on the south-east of Mont Blanc, which was very extensive, consisted of masses of granite, serpentine, quartz of all colours, talc, potstone, micaceous schist, veins of amianthus, and varieties of shorl [g].

If we pass from the consideration of the Alps to the Pyrenees, we shall find that Ramond, at the end of ten years acquaintance with these mountains, says, "The more I observe, the more I perceive the necessity of observation, and the less I rely on that which I have observed [h]." In another publication the general arrangement of these moun-

[e] Saussure, tom. v. p. 461.
[f] Ibid. tom. ii. p. 234.
[g] De Luc, Lettres, tom. v. p. 413.
[h] Ramond, p. 319.

tains is thus described. When standing on the top of Mont Perdu, the highest summit of the Pyrenees, you see to the north a range of primitive mountains, whose high and craggy peaks entirely intercept the view of the plains of France; while to the south is a tremendous precipice of more than three thousand feet in height, the bottom of which is formed by the tops of the highest mountains of that part of Spain. The height of these mountains, ranged at the foot of the precipice above mentioned, is seven thousand feet; but they soon pass off into low round-topped hills, beyond which the plains of Arragon are seen in immense perspective [i].

Humbolt does not believe in that parallelism of mountain chains which he says geologists are apt to insist on; and which geographers represent on their charts like regularly elevated dykes [k]: and with respect to the mineral contents of mountains, he says, that although many of the mineral depots of New Spain, and some of a very peculiar character, agree with similar European formations [l]; yet the systematic ideas of some geologists of celebrity, respecting the distribution of metals according to peculiar latitudes, appear to be entirely vague when compared with facts [m]. The geological observations of the same philosopher led him to conclude, that slight causes influenced nature sometimes to elevate the highest summits near the

[i] Annales du Mus. tom. iii. p. 74, &c.

[k] Humboldt, tom. i. p. 163.

[l] Ibid. tom. iv. p. 118.

[m] Ibid. tom. iv. p. 165.

centre, and sometimes near the exterior part of the Cordilleras. Thus in passing from Mexico to Acapulco on the west side, you cut at right angles three or four longitudinal vallies: but in passing to Vera Cruz on the east side, you first travel across the table land, and then descend at once without the interruption of any longitudinal valley [n].

The following descriptions of the Cordilleras of America, and of the Gauts of the peninsula of India, will serve to shew the difference between these, and any of the groups of European mountains. The chain of the Cordilleras, the most elevated group of which chain is near the capital of Mexico, has been ascertained by actual observation to extend through New Spain in a line nearly parallel to the Western Ocean [o]. The summit of this chain, very unlike the ridges of mountains in general, is an elevated tract of country, which through the length of five hundred leagues is never less than from five to six thousand feet above the level of the sea: and there is a carriage road throughout that whole extent [p]. The extent of this flat ridge or platform of the Cordilleras may be conceived from the following statement; that of a population of four millions, which occupies the equinoctial part of Mexico, more than three millions inhabit the platform; and throughout one hundred and forty leagues from Mexico northwards there is nearly the same level;

[n] Humboldt, tom. i. p. 279.
[o] Ibid. p. 111.
[p] Ibid. p. 135 and 165.

the height of which above the ocean is the same as that of St. Gothard, the great St. Bernard, and Mont Cenis[q]; its medium temperature being about equal to that of Rome[r]. The rivers derived from this part of the Cordilleras have but a very short course; and do not flow, like those of the Alps and other mountains, from the elevated regions; but issue out at the distant feet of the mountains: this circumstance in the history of the Cordilleras is explained by the small quantity of rain which falls, and by the rapidity with which evaporation goes on at the height of the table land; and also by the nature of the prevailing rocks, which are porous amygdaloids and porphyries full of crevices, that readily suffer the water to filter through their substance.

Major Rennell observes in his account of Hindostan, that a stupendous wall of mountains, called the Gauts, rises abruptly from the low country, and flanks nearly the whole of the western coast of the peninsula of India; and that these elevated mountains in the foregoing respect, and in some others also, resemble the Andes of America. They extend for instance in a line parallel to, and rarely distant from, the coast more than seventy, but usually about forty miles[s]. They support in the nature of a terrace a vast extent of fertile and populous plains, which are so much elevated as to render the air cool and pleasant[t]: and

[q] Humboldt, tom. ii. p. 78, and tom i. p. 269.

[r] Ibid. tom. i. p. 288.

[s] Rennell's Hindostan, p. 213.

[t] Ibid. Introd. p. 127.

all the great rivers to which they give rise flow towards the east; while none of any consequence are formed on their western side.

But there is not any resemblance even between the Andes of South and of North America. Thus it is observed by Humboldt, that though the chain of mountains which forms the vast platform of Mexico is the same with that which in South America is called the Andes [u]; yet the difference between the northern and southern Andes is very great. The vallies of Quito &c. in South America are not comparable to those of Mexico; but are, like the longitudinal vallies of the Alps, bounded by parallel branches of the Andes, which are every where transversely torn and interrupted by chasms, resembling open or imperfectly filled veins; while in Mexico it is the very summit of the mountains which constitutes the platform, or that part which is analogous to the high vallies of alpine land in general. In Peru the most elevated summits form the crest or ridges of the Andes. In Mexico the summits are either irregularly dispersed over the platform, or are ranged in lines which have no relation of parallelism with the direction of the Cordilleras [x]. In South America the transverse vallies, frequently above four thousand feet deep, entirely interrupt travelling in a northerly or southerly direction, excepting on foot or horseback: but in North America carriages pass uninterruptedly from the capital of Mexico to Santa-Fe in New Mexico, a distance of fifteen hundred miles [y].

[u] Humboldt, tom. i. p. 267. [x] Ibid. p. 268. [y] Ibid. p. 268.

To return to the consideration of some of the groups of European mountains, it is stated by Daubuisson, that the Erzegebürge, a chain of metalliferous mountains, separating Saxony from Bohemia, and extending one hundred and thirty miles in a north-easterly direction, is very steep on the Bohemian side; but on the side of Saxony very gently sloping, and covered with forests and mines [z]. And De Luc says with respect to the Hartz, that peaks which are so abundant in the Alps, Apennines, and Pyrenees, do not occur in that group of mountains; and yet the species of rocks are the same there as in other mountainous districts [a]. The appearance of the Hartz, as described by De Luc, is very like that of Dartmoor; presenting rounded waving summits without any escarpments, with here and there a rocky point or tor projecting from the surface [b]: and he adds, that the granite, which forms the mass of the Brocken, the central part of the Hartz, extends a certain way; and then nothing is seen but irregularly laminated schist [c]. In our own island the Malvern Hills on the side towards Worcester terminate almost abruptly in a level plain of rock marl, out of which they seem to rise; while on the opposite side they give support to a variety of beds of a very different nature, and forming a rugged surface.

Having insisted so much on the numerous

[z] Daubuisson, p. 17 and 99.

[a] De Luc, Lettres, tom. iii. p. 165.

[b] Ibid. p. 275.

[c] Ibid. p. 278.

irregularities observable in the arrangement of mountains, I ought not to omit mentioning that both Saussure and Humboldt take notice of one point, in which there is a tolerably constant uniformity; the parallelism, that is, of the strata of the principal chains to the great or longitudinal vallies by which they are bounded. Thus Saussure, in speaking of the great longitudinal valley in which the Rhone flows previously to its entrance into the lake of Geneva, says, that it has this essential character of longitudinal vallies, that the mountains bounding it have their strata parallel to the direction of it[d]: and Humboldt indirectly notices the same fact; for in observing that the strata of most of the primary rocks of Mexico have a direction from south-east to north-west, and that the parallelism of the strata through a vast extent of country is a most important fact, adds, that even at a great distance from the central chain, the direction of the high chains of mountains seems to influence remarkably the direction of the strata[e].

I shall conclude this chapter with a remark on the correspondence between the form or outline of individual mountains, and their internal character; on the uniformity of which correspondence I conceive much too great stress has been laid. I do not mean to deny that some rocks are, from a peculiarity in their internal structure, disposed to separate, in consequence of the action of mechanical

[d] Saussure, tom. viii. p. 9, and tom. vii. p. 290, 292.

[e] Humboldt, tom. iii. p. 385.

or chemical causes, into masses of a polyhedral or other symmetrical form; as is the case frequently in the granite tors of Cornwall and Dartmoor: but it is clear, as well from antecedent reasoning as from actual observation, that if there be no such peculiarity in the internal structure of a rock, the effects of external agents must be modified simply by its power of resistance; and hence there may occur perfectly round-backed hills of granite and serrated peaks of schist or limestone. Saussure mentions a mountain consisting of tourmaline, quartz, and hornblende, which is perfectly round-backed; though most of the mountains of the same chain terminate in peaks: it separates two of the highest glaciers of the Alps, but is of a mouldering nature [f]: and the same accurate observer remarks, that granitic summits are sometimes rounded, sometimes in acute-angled peaks; and that even calcareous summits, if hard and vertically stratified, form acute peaks [g].

I here conclude this chapter; and from even the cursory examination contained in it, I think it appears, that whether we consider the *succession* of the strata in a mountainous district, or the *arrangement* of the mountains one with another, or the *forms* of individual summits, scarcely any point of general uniformity is observable; each group, and almost every distinct part of each group, having its own peculiarities.

[f] Saussure, tom. iv. p. 22. [g] Ibid. tom. vii. p. 269.

CHAP. XVII.

On Beds of Gravel.

HAVING finished the examination of the strata, I proceed to speak of those depositions usually called *alluvial,* as beds of gravel &c. which have taken place since the formation of the strata themselves. Among such depositions those accumulations of gravel, which are found in every part of the world under nearly similar circumstances, are of all the phenomena of geology accompanied with the most unequivocal testimony both of the comparative date and nature of their origin; for they evidently are water-worn fragments of the regular strata, and being always found incumbent on, they must necessarily have been deposited subsequently to them. Their depth indeed sometimes extends to more than two hundred yards, but they are never subjacent to any stratum; and they are sometimes found lying immediately on the lowest of the strata; but this would necessarily be the case as often as the deposition of gravel took place in parts where the lowermost strata happened to occupy the surface.

If I were to judge from what my own experience has shewn me in this island, joined with descriptions of other parts of the world, I should conjecture, that a very considerable proportion of the former surface of the earth has been covered by gravel; the local character of which is in a great measure determined by the character of the

strata in its vicinity; but a description of the gravel bed of the neighbourhood of Oxford will be illustrative of the nature of these beds in general.

The bed of gravel on which Oxford stands, which extends, with occasional interruptions, to the distance of many miles in every direction, consists principally of fragments of the coarse calcareous freestone and indurated portions of the iron sand, of which most of the neighbouring hills are composed. It also contains fragments of flint, which may easily be referred to the chalk strata situated at an average distance of from twelve to fourteen miles. As these constituent parts occur severally in a proportion corresponding to the prevalence and vicinity of the strata from whence they have been derived, and as the bed of gravel itself occupies upon the whole the lowest level, there is no difficulty in admitting the probability that it was formed by means of water which detached and wore down portions of the adjacent strata: but then, mixed with these fragments, the native beds of which are found in the immediate vicinity, are found pebbles of quartz and of various rocks, none of which are known to occur within a distance of fifty miles; and frequently both the size of these foreign fragments is larger, and their degree of hardness greater, than that of the native strata of the neighbourhood.

In Bagley Wood, and on a part of Wytham Hill, which places are situated about two or three miles to the west of Oxford, there is a coarse gravel at a considerable height above the level of the sur-

rounding country, many of the masses of which are each of several pounds weight; and apparently derived from a district abounding in compact quartz rock, fine-grained micaceous gritstones, and obscurely defined compounds of hornblende and felspar; which last often assume a porphyritic character. This coarse gravel contains few, if any, fragments of the neighbouring strata, and is altogether of a character so distinct from the gravel of the plain below, that it is difficult to suppose the two are parts of the same bed; and at one time it was my opinion that they must have each had a distinct origin: but upon the whole it seems most probable, that, however different in character, they must have been deposited by the operation of the same cause; for in other spots the constituents of both are found mixed together, if my recollection serves me, in proportions nearly equal: but I do not speak positively on this point, having been unable to give it the necessary degree of attention.

Among the contents of the Oxford gravel are fragments of teeth and tusks and bones of elephants; horses teeth; bones of the hippopotamus (unless I am mistaken); and horns of a species of stag: and in this respect the gravel of Oxford corresponds with many similar depositions not only in England but in various parts of Europe. It is remarkable that the surfaces of these bones &c. are sometimes in almost as complete a state of preservation as if they had never been moved from the spot where the animal died. Thus there is in the Ashmole Museum a part of a stag's horn from

this gravel, in which all the natural grooves or channels, in which the blood-vessels of the velvet of the horn formerly ran, remain uninjured; but the tip of a projecting branch near the root of the horn is worn smooth, as if (judging from the entire state of all the rest) the attrition had taken place during the lifetime of the animal.

In travelling from Oxford to any distant point the character of the several gravel beds, occurring in the way, alters according to the nature of the surrounding country: thus as you approach the chalk range, fragments of the strata immediately subjacent to the chalk appear, and the proportion of flint increases; and immediately in the vicinity of and on the chalk, the fragments of flint form more than nine tenths of the whole mass. Or if pursuing other directions you travel into the central part of the kingdom, you meet with gravel made up principally of the *débris* of the strata prevalent in those parts. I have made the same observation in Devonshire also and in South Wales.

I have already said, that the natural strata are sometimes so loosely compacted as to have been mistaken for depositions of gravel: and on the other hand depositions of gravel appear sometimes to have been confounded with the regular strata. Even Saussure in the opinion of Mr. Playfair has fallen into this error[h]; and De Luc appears to me to have committed the same error on some occa-

[h] Playfair's Illustrations, p. 384.

sions, for he has confounded stags' horns and elephants' teeth (which I presume every experienced geologist will recognize as met with hitherto only in gravel or similar depositions) with the fossile contents of the regular strata. And Werner also, if I may venture to say so, seems to have confounded gravel with trapp rocks of the most recent formation; for, according to Mr. Murray, he says, that he found deers' horns in wacken[i].

In this part of the world depositions of gravel are neither found at any high level, nor are the fragments of which they are composed of any remarkable size: but in America they occur at heights greatly above the level of the summit of the highest mountain in Britain. Thus Humboldt informs us, that bones of the fossile elephant were found in making an artificial outlet for the waters of inundation from the valley of Mexico, at an elevation of more than 5,000 feet above the level of the sea[k]. And Faujas says, that immense bodies of quartzose gravel mixed with particles of gold and of platina, and with the remains of elephants and other large animals, surround the Cordilleras of Choco, and of Santa-Fe, &c.; forming mountains which reach to the height of nearly 8,000 feet above the level of the sea[l].

The animals particularly characteristic of gravel beds are the elephant, rhinoceros, horse, and va-

[i] Murray's Comparative View, p. 252.

[k] Humboldt, tom. ii. p. 235.

[l] Essai de Géologie, tom. ii. p. 330.

rious species of the deer, buffalo, and other large animals of the ruminating class: the associations of which are sometimes very remarkable. Near Canstadt, for instance, in the neighbourhood of Stutgard, fossile remains of elephants occur mixed with fossile bones of the hyena and horse: and it is remarkable that the horses' *teeth* occur in amazing quantity, while the *bones* of the same animal do not occur in the proportion of one to ten compared with the teeth. A similar coincidence of the remains of the hyena, elephant, and horse, has been met with in the fissure of a calcareous rock, in ci-devant Franche Comté, near one of the sources of the Rhone[m].

But of all the organic remains occurring in gravel and similar depositions, those of the elephant seem to be of most frequent occurrence: and it is to this fossile animal, and not to the fossile animal of America exhibited in London some years since, that the term "mammoth" strictly belongs; the term, which literally signifies the *subterranean animal*, having been originally applied to the fossile elephant of the north-east of Europe and Asiatic Russia; in which parts of the world its remains occur in such remarkable abundance as to have been for many ages past a permanent article of commerce; being employed, for one purpose among others, as a medicine: on which Leibnitz justly remarks, "Ita facti sunt homines, ut, quicquid specie aliquâ præstat, etiam virtute eminere arbitrentur[n].

[m] Ann. du Mus. tom. vi. p. 127—137.

[n] Leibnitz, vol. ii. part. ii. p. 224.

The following notices of the occurrence of the remains of the fossile elephant form but a small proportion of those which I might have collected from Pallas. These remains are found near the entrance of the Oural into the Caspian [o]; also on the banks of Volga in north latitude 55 [p]: and about the same latitude, on the banks of many of the tributary rivers of the Volga and Oural, fossile heads and other parts of elephants are found in a good state of preservation [q]. Marine shells with heads of large fish, and buffaloes' and elephants' remains occur in clay banks on the river Irtisch [r]. And, according to Cuvier, Pallas observes, that throughout Asiatic Russia from the Don to the extremity of the promontory of the Tchutckis there is not a great or small river, especially of those whose course is along a plain, near the banks of which have not been found the bones either of elephants or of other animals foreign to the climate [s]. The tract of country in which these remains were found by Pallas is not less, according to Mr. Playfair, than 4,000 miles [t]. I omit mentioning the extraordinary relation of the fossile elephant found with its skin and even hair entire in a mass of ice, as it must be fresh in the recollection of most of my readers.

If from that part of the Russian empire which Pallas visited you travel across the continent of

[o] Pallas, tom. i. p. 598.
[p] Ibid. p. 214.
[q] Ibid. tom. ii. p. 10.
[r] Ibid. tom. iii. p. 125, and 144.
[s] Ann. du Mus. tom. viii. p. 46.
[t] Playfair's Illustrations, p. 471.

Europe, it appears, that though neither in so perfect a state of preservation, nor in such abundance, yet the remains of the fossile elephant are of frequent occurrence; nor did the British Channel, if it existed at the time when these depositions of gravel were formed, intercept the transportation of these organic remains. The frequency of them seems to diminish in proportion as you advance westward from Siberia, and this of itself is an argument in favour of the animal having originally inhabited that part of the world. A much stronger argument however is deduced from the nearly perfect state of preservation in which Pallas says they are there sometimes found: and Cuvier has obviated the great objection raised on the physical impossibility of the existence of the elephant in such northern latitudes, by having ascertained that there is a greater difference between the fossile elephant and either of the two living species, (the African and Indian,) than in other cases is observable with respect to existing species of the same genus which are known to inhabit equally distant climates; for instance, the Indian and African jackall and the Siberian jackall[u]. It is remarkable that the *fossile* elephant is met with in America where no *living* species of that animal exists: and yet it is questionable, according to Cuvier, whether the fossile remains of elephants occur in those climates which the living species frequent[x]. So again the *fossile* tapir is met with in the old continent; the *living* tapir only in the new[y].

[u] Ann. du Mus. tom. viii. p. 265.

[x] Ibid. p. 53.

[y] Ibid. p. 420.

Accumulations of gravel are so evidently referable to the action of water, that the only question can be as to the mode of that operation: and although in mountainous districts these accumulations may with some probability be attributed to the action of rivers, they cannot, I think, be attributed to the same cause in level tracts of country. The following appear to me convincing arguments against the probability of their origin from such a source. Mr. Farey says, that about Nottingham and Mansfield there is a bed of gravel, from two hundred to three hundred yards in thickness, consisting of sand and highly rounded quartz and other siliceous pebbles. A part of this gravel extending across Derbyshire into Staffordshire, contains fragments of chalk, and of chalk flints, and of other strata of the S. E. of England[z]. But it seems evident that as the rivers of the S. E. of England flow from this point, they cannot have conveyed the gravel to the same point. Again, if rivers had transported the materials of gravel beds, the character of the gravel at a *lower* point of the river ought to correspond with the beds of a *higher:* but the Oxford gravel, and the gravel of Bensington under the chalk hills, correspond each with the strata of its neighbourhood.

If the stream tin works of Cornwall, which are somewhat analogous to gravel beds, were the work of rivers, why does not the process go on? or why is all the tin at the bottom? For, as in the instance of the alluvial ground of Holland, which is known

[z] Farey, vol. i. p. 132.

to have been deposited by the neighbouring rivers, and which consists of several alternations of similar beds, there ought to be *alternations* of tin and sand: since, though in each fresh process the weight of the tin would take it to the bottom, it is not to be supposed that the tin of the second process would sink through the sand of the first. I do not see how the Thames and Cherwell can have possibly deposited the teeth of fossile elephants in the gravel of Oxford: or if they have ceased to do so, because elephants are extinct in this island, it may be asked, why do they not deposit the bones of existing species? But it may be fairly said, as gravel beds do not appear to be progressively increasing, that no existing cause can have occasioned their original deposition.

Saussure is decidedly adverse to the hypothesis that the rivers of the Alps have accumulated the alluvial depositions which surround those mountains, and grounds his opinion on such facts as the following[a]. In the vale of Susa near Rivoli is a bed of large gravel which reaches nearly 1,800 feet up the flanks of the mountains forming the exterior chain of the Alps towards Piedmont: these mountains abound in serpentine, a rolled block of which near Rivoli is fifty feet in length, twenty in breadth, and twenty-five in height[b].

The fossile rhinoceros, said by Pallas to have been found on the banks of the Viloui, near its junction with the Lena, was contained in a large grained gravelly sand, at a depth at which the

[a] Saussure, tom. v. p. 170. [b] Ibid. p. 156, 170.

moisture remains always frozen; and this indeed preserved it in so fresh a state[c]. Now the river could hardly have brought this whole animal; or, if it did, the climate must have undergone a wonderful change since that period: and that change must have been sudden, or putrefaction would have previously taken place in the animal.

It is stated by Dr. Mac Culloch, that on the top of Staffa is a bed of gravel containing rounded masses of granite, gneiss, micaceous schistus, quartz, and red sandstone; yet many of these rocks do not occur in Staffa: and of the adjacent islands, Coll, Tirey, and Mull, are the only ones likely to have afforded them: but if this be their source, "even then," Dr. Mac Culloch says, "we must admit that Staffa has formed part of one continuous land with those islands, since no transportation could have been effected without the existence at some period of a continuous declivity between them. And equally unsupported by any thing that is now going on would be the supposition that Staffa rose from the sea, with these rolled masses that were previously distributed on its surface[d]." Again, it is stated by Mr. Farey, that on the banks of the Trent, Dove, and Derwent, are several alluvial flats of considerable width, and from one to several feet in thickness, *producing excellent meadows*: and he observes, that as these tracts lie over the great gravel bed of this part of the country, it is clear that that gravel must have

[c] Pallas, tom. iv. p. 133. [d] Geol. Transact. vol. ii. p. 508.

been deposited by a very different agent from that which formed the alluvial meadows[e].

Cuvier and Brongniart, in speaking of the uppermost formation of the basin of Paris, called by them *formation du limon d'atterrissement*, and evidently analogous to a gravel deposition, say, that this formation bears sufficient marks of having been deposited not by the action of any existing river however violent, but by some extensive irruption of water. For the present force of the most violent inundations of the Seine is unable to transport a pebble no larger than the head of a man; and never, besides, reaches the level of the upper part of this formation: whereas this formation contains great blocks of sandstone and millstone, which have evidently been conveyed from a distance. It also contains rolled masses of granite and other primitive rocks[f]. Lastly, Faujas states, that the gold found in the sand of the Arve, the Rhine, the Rhone, and many other rivers, does not appear to have been separated by them from the rocks from whence they have their source[g]: and Cornwall affords a similar instance in the case of the stream works; no gold having been, I believe, found in the native rocks of Cornwall, though the stream works have sometimes yielded it in considerable quantity.

It is usually supposed that the organic remains of gravel are often referable to existing species: but whoever follows the detail of Cuvier will, I

[e] Farey, vol. i. p. 133. [f] Ann. du Mus. tom. xi. p. 233, 235.
[g] Essai de Géol. tom. ii. p. 329.

think, be inclined to doubt whether the correspondence is so frequent as has been supposed. Many of the remains, as of the elephant, the rhinoceros, the tapir, the mastodon or fossile animal of the Ohio, are decidedly of extinct species; and Cuvier asserts, that in the class of ruminantia, which are of very common occurrence in gravel, it is extremely difficult to distinguish the specific difference; the proportions of some of the principal parts, as of the horns for instance, being no criterion of the size of the whole body. Of the truth of the assertion just mentioned, a singular instance is given by Mr. Salt; who says, that though the horns of the Galla oxen, which are celebrated throughout Abyssinia, are sometimes four feet long; the circumference at the base being twenty-one inches; yet the size of the animal does not exceed that of the common ox[h]. Cuvier and Brongniart, after having said of the gravel deposition in the basin of Paris, that it contains bones of elephants, oxen, antelopes, elks, and other great mammifera, add, that although the most superficial of all the formations of that basin, it is yet anterior to all history; since the animals there found are not only different from the animals now existing in that country, but even from any animals hitherto known to naturalists[i]. In another part they observe, that the alluvial depositions of the ancient earth resemble in nothing the similar depositions of the present earth[k]. And Cuvier on another

[h] Salt's Abyssinia, p. 259.

[i] Ann. du Mus. tom. xi. p. 57, 237, and 326. [k] Ibid. p. 58.

occasion says, that probably there may be gravel beds of different dates; some containing existing, some extinct species[1].

It is very commonly supposed also that depositions of gravel are the consequence of the Mosaic deluge; against which supposition, I think, the following is a strong argument. The period which intervened between Adam and Noah is as long as between Noah and the building of Rome: but at the time that Rome was built it appears from historical evidence that a great part of Europe was peopled, and that even our own island was inhabited. Reasoning then on that datum, the same parts were probably peopled at the time of the flood (especially as human life extended to a longer period before than after that catastrophe); and consequently we might expect to find the remains of human bodies, and of instruments of art, in such situations as we find the remains of other animals; if these last mentioned remains are the monuments of the Mosaic deluge: or, if not the remains of human bodies, at least we might expect to find the remains of existing as well as of extinct species: for we learn from Scripture, that the flood was only intended to destroy individuals; the species having been miraculously preserved. It may be said, that the absence of human remains is a negative argument, which may be overturned the next moment by the discovery of the remains of human bodies in beds of true gravel. This is however not likely; and at all events it is evident, that the

[1] Annales du Mus. tom. xii. p. 398.

history of gravel beds is accompanied with facts as inexplicable as are found in the history of the regular strata. But, whatever were the cause of the deposition of gravel beds, it appears pretty certain that no process of that kind took place at any period between the formation of the earliest and the latest of the regular strata: for I cannot find that any thing resembling a true gravel bed is interposed between any of the series of any formation: yet if stratification were now to be resumed, it is clear that the existing beds of *gravel* would be covered as well as the uppermost of the *regular strata.*

Before I conclude this subject, I wish to make a few remarks on the stream works of Cornwall; and on the depositions in which Bovey coal, and that apparently analogous substance the umber of Cologne, are found.

For the general history of the stream works I refer the reader to my Outlines of Mineralogy[m]; to which I have only to add, that if the tin ore in those works and the sand &c. by which it is covered are of cotemporaneous origin, it would appear that these depositions are more recent than alluvial depositions in general; because both the remains of human bodies and implements of art have been found in them: but as we are yet in want of an accurate description of the stream works, it would be imprudent to speculate upon their history.

For the general account of Bovey coal and the

[m] Vol. ii. p. 147, 148.

argillaceous beds accompanying it, I also refer the reader to my Outlines of Mineralogy[n]: but I believe there is one material error in that account; for I have reason to think, from a recent examination of the spot, that the roots of trees there described are entirely unconnected with the Bovey coal, and belong to a peat formation which has taken place subsequently to the deposition of the coal, and its accompanying argillaceous beds: but this also is a spot which evidently requires a more accurate examination than it has yet undergone. It remains then for me to speak of the deposition in which the umber of Cologne occurs; of which the following account has been formed from the Annales du Muséum[o].

The umber of Cologne (*terre d'Ombre*) occurs in pits, called turf pits, in the vicinity of Bruhl and Liblar, distant about four leagues from Cologne. The Bruhl pit is near the top of a mountain, and is an open quarry excavated in a stratum of very black earth of considerable thickness. This stratum of black earth is covered by a bed of rolled pebbles, nearly all rounded; the average thickness of which pebble bed is twelve feet. The pebbles do not usually exceed the size of an egg; are commonly of white or greyish yellow quartz, with some pieces of brown and red jasper; and are occasionally mixed with a little sand or clay. This bed rests immediately on the umber, which has been excavated to the depth of from twelve to thirty feet.

[n] Vol. i. p. 167, 168. and vol. ii. p. 45—49.

[o] Ann. du Mus. tom. i. p. 445.

The whole bed of umber is evidently composed of the decayed ligneous fibres of various kinds of trees: here and there pieces occur less decayed, and of several inches in length; some of which are as black as jet or ebony. The bed contains neither clay nor sand, but is entirely composed of ligneous fibres, with here and there particles resembling bitumen; and pieces completely resembling charcoal.

The Liblar pits are very extensive; and many villages are occupied in working them. In these pits whole trees, but stripped of their branches, occur; and the wood is sometimes pyritical. The Liblar umber, like that of Bruhl, is covered by a bed of rolled pebbles about ten feet thick; but at Liblar there sometimes occur among the pebbles masses of rounded quartz from sixty to eighty pounds in weight. In some places there is a thin layer of sand or clay between the umber and the bed of pebbles; and this layer of sand or clay always contains ligneous particles resembling the umber. Sometimes there are converging fissures penetrating six feet deep into the umber; and these fissures, which are from one to two feet wide at their commencement, terminate in a point: they are filled with pebbles, like those which have been already mentioned.

The pits both of Bruhl and Liblar are in elevated situations, being four hundred feet above the bed of the Rhine; which river is three leagues distant from them. The nature of the umber remains the same to the depth of forty feet; below which, water and deleterious gases prevent the working.

The fossile trees occurring at Liblar are more firm and compact the deeper they occur; and will sometimes even bear the saw: but contact of air soon decays them. Trunks of trees have been found at the depth of thirty-five feet; but branches or roots are never found: so that probably they were either palm trees which have no lateral branches, or they have had their branches worn off in being brought from a great distance to the present spot. Here and there the fruit of these trees is found, resembling a common nut in form, but differing from it in structure. Jussieu, Lamarck, and other celebrated botanists, refer these fruits to a species of palm growing in India; for they closely resemble the fruit of a palm of the Molucca isles, and of the southern parts of China.

CHAP. XVIII.

On insulated Masses of Stone, commonly called Boulders.

THOSE insulated masses of stone, which are of such common occurrence in every part of the globe, have probably been scattered over its surface by an operation similar to that which produced depositions of gravel: for they have evidently been water worn; and, judging from the identity of their internal character, have as evidently once formed a portion of some of the native strata. Such stones are by Saussure called "cailloux

roulés;" and he observes, with De Luc, that the gradual removal of these stones for the purposes of building, in proportion as population increases, is a chronometer, which shews that the human race is not very old[p].

It was Saussure's opinion that the waters of the ocean, in which he supposes mountains to have been formed, were still in part covering those mountains, when a violent earthquake all at once opened numerous subterranean cavities, and rent asunder many of the strata. The waters then rushing towards those cavities, with a violence proportioned to the height of their level, excavated deep vallies, and carried with them immense quantities of earth, sand, and fragments of all kinds of rocks. This half liquid accumulation, hurried on by the weight of the water, lodged itself at those heights where we still see many of the scattered fragments. The waters afterwards continuing to run, but with a rapidity gradually lessening in proportion to the diminution of their height, carried away by little and little the lightest particles; and cleared the vallies of the heaps of mud by which they had been clogged, leaving behind either the heavier masses only, or those also, which accidental position or an unusually settled lodgment protected from their action[q].

A rush of water, like that just described, Saussure calls a *débacle;* and the sudden eruption of a mass of water from any barrier which had previously confined it would represent the effects of

[p] Saussure, tom. iv. p. 388.

[q] Ibid. tom. i. p. 205.

a debacle on a small scale. The great debacle, to which in his writings he so often alludes, is supposed to have been occasioned by the sudden retreat of the waters of the chaotic ocean, as above described: and he thinks it probable, that the beds of the principal Alpine vallies have in many instances been formed by sand and gravel brought by the great debacle[r]: and that rivers, (as in the valley of the Durance which rises in high Dauphiny,) by washing away the earth and sand mixed with the pebbles that have been formerly deposited, bring these pebbles to view[s].

Thus, he observes, the tract between the Durance and Avignon on the Rhone is a perfectly level plain without a pebble; for the silth which the Rhone brings down, and deposits in the time of its floods, levels the neighbouring country, and completely hides the pebbles of the ancient currents[t]. Again he remarks, that, in travelling to the N. E. of Avignon, while the country is of a low level, the pebbles are covered with the sand &c. brought down by the Rhone and its tributary rivers: but when the level of the country rises, so as to be out of the reach of the overflowings of the rivers, the pebbles or boulders are seen in great quantity[u]. And soon afterwards he observes, that the size of the pebbles found in the neighbourhood of Avignon is such that the Rhone could never have brought them[x]. He at the same time notices,

[r] Saussure, tom. ii. p. 208.
[s] Ibid. tom. vi. p. 77.
[t] Ibid. tom. vi. p. 77.
[u] Ibid. tom. vi. p. 86.
[x] Ibid. tom. vi. p. 90.

that almost all these pebbles are of white, yellow, or red quartz; and that they form a bed, which occupies nearly the whole of the valley of the Rhone from between Lyon and Jura to below Avignon; and yet, which is most remarkable, neither in the mountains which border the Rhone, nor even in the chains which are adjacent to those mountains, is there any stratum of quartz rock, or even of siliceous gritstone[y]. So again he argues, that the basaltic masses of several quintals in weight, which are found on the left bank of the Rhone, and extend to a considerable distance from the river, could never have been brought by the river itself; no such rocks existing on its left bank: so that they must probably have come from the Vivarais on the right bank[z].

But of all the proofs which he brings in favour of his opinion, the following is the most remarkable. The plain of Crau, the *campus lapideus* or *Herculeus* of the ancients, occupying a triangular area of nearly twenty square leagues, (the apex adjoining the Mediterranean sea, the base extending from east to west,) is covered with boulders, which by some are supposed to have been brought thither by the Rhone; by others, by the Durance. Nearly seven eighths of these boulders are a very close-grained gritstone, usually of a white colour; though sometimes yellow or red[a]. The size of the boulders near the surface is commonly that of a man's head; from which circumstance Saussure is

[y] Saussure, tom. vi. p. 91.
[z] Ibid. p. 94, 95.
[a] Ibid. p. 141, 144.

decidedly against the hypothesis that they have been brought down either by the Durance or Rhone: for these rivers now bring down only sand, which covers and fills up the intervals of these boulders [b]. He supposes therefore, that when the waters of the ocean abandoned our present continents, to retire towards the gulphs which they now occupy, a violent current, hemmed in to the west by the mountains of the Vivarais, and on the opposite side by the mountains of Dauphiny and Provence, carried down fragments from all those mountains, (and fragments of all those mountains are found in this plain,) and deposited them in the open space formed by the mutual divergence of the mountains from each other [c].

Saussure often speaks of the marks of a watercourse that has corroded the rocks, in narrow passes, much above the level of any river in the neighbourhood [d]: and on several occasions observes, that in high Alpine vallies surrounded by high summits you never meet with pebbles of a different character from the strata of the valley; but in the plains, even when they are of considerable elevation, you find pebbles of all kinds; so that you might suppose they had fallen from the clouds, so very different are they in their character from the surrounding strata [e].

On the sandstone hill called Boissy, to the south of the Lake of Geneva, but on the north-east

[b] Saussure, tom. vi. p. 151.

[c] Ibid. p. 152.

[d] Ibid. p. 4.

[e] Ibid. tom. iii. p. 176; tom. iv. p. 206; tom. v. p. 83.

of that city, is an enormous fragment of rock, the cubic contents of which are above ten thousand feet; its dimensions being, in length twenty-six feet, in height twenty-two, in thickness eighteen; it consists of a hornstone or trapp rock, having a stratified structure, mixed with steatite and quartz and mica. Saussure adds, that he recognized exactly such a rock in the high Alps [e]. On another occasion he says, that in several parts of the Lake of Geneva may be seen immense blocks of granite, hornstone, schist, or some other primitive rock; that the bottom of the lake is covered over in various places with primitive rolled masses; and the rock at the entrance of the port of Geneva, called *pierre à Niton*, (a corruption of Neptune, to whom it was anciently dedicated,) is a granite, which, as well as all the other blocks, must have been transported thither from the high Alps; which in a straight line are distant ten leagues [f].

In two instances large blocks of granite are found resting on pedestals of limestone, the upper surface of which pedestals, he thinks, has been protected by the incumbent granite, while the sides have been eroded by running water [g]. This opinion receives a great degree of confirmation from the corresponding fact, that sometimes among the glaciers of the Alps an enormous fragment of rock, brought down by an avalanche, and resting on a mass of ice, forms by degrees a pedestal for itself; the surrounding ice melting, while that of the pedestal is protected by the block which it supports [h].

[e] Saussure, tom. i. p. 343.
[f] Ibid. p. 21.
[g] Ibid. p. 226.
[h] Ibid. tom. iii. p. 45.

Many of the phenomena of scattered boulders recorded by De Luc are, like those of Saussure, characteristic of the action of a great and extensively acting flood of water. Thus on the coast of the Baltic near the island of Rugen are hills of chalk, containing common black flint and the usual fossils, covered with blocks of granite and other primitive rocks[i]: and the blocks of granite scattered over the sandy hills of Holstein are much larger than the large stones of Stonehenge[k]. In different parts of Westphalia, Lower Saxony, and Pomerania, there are occasional large heaps of granite and other primitive rocks, covering several acres, and distant from any mountains: and in receding from these heaps, whether towards or from the mountain districts, the number of these stones decreases till you come to new heaps; the genera and species of these new heaps being usually found to differ from the preceding[l].

In Lower Saxony there are many circular ridges of hills, forming an amphitheatre so nearly complete as to leave only an outlet for a rivulet: and it is remarkable that the sides of these hills looking towards the centre of the amphitheatre are strewed in great quantity with blocks of granite, porphyry &c. and even with chalk flints[m]: but the size of the masses does not follow any regular order connected with their situation[n]. De Luc, in giving an instance of one of

[i] De Luc, Lettres, tom. i. p. 248.

[k] De Luc's Travels, vol. iii. p. 492.

[l] Ibid. p. 492.

[m] Ibid. vol. i. p. 64 and 123.

[n] Ibid. p. 121.

these amphitheatres in the neighbourhood of Oranienberg, about twenty miles to the north of Berlin, adds, that the pebbles are principally of a kind of granite, of which he never saw any in the nearest mountains [o]. It was the opinion of M. Meierotto of Berlin, that the heaps of scattered blocks found in Westphalia &c. were formerly brought thither enveloped in masses of ice, which had been floated over from Sweden [p].

De Luc however is at variance with Saussure on one, and that an important point. He says it was the opinion of Saussure, that a great debacle had transported the *débris* of the Alps so as to reach the Jura chain; but that this debris is only found in the transverse vallies of Jura which have the Alps in view, not occurring in the longitudinal vallies, which lie parallel to the bearing of the chain of Jura; the escarpment of the chain having acted as a barrier. De Luc however asserts, in stating Saussure's opinion, that this is not the case; and that this debris occurs also in the longitudinal vallies most distant from the Alps [q].

I remember that, in travelling through a part of Scotland in 1806, a similar observation to that of Saussure's above mentioned [r] struck me very forcibly; small streams often, in their course through broad and almost level vallies, washing away the earthy particles from a large grained gravel, which formed the bed of the valley; and which it did not seem possible to me could have

[o] De Luc's Travels, vol. i. p. 129.
[p] Ibid. p. 57 and 219.
[q] Ibid. vol. iv. p. 4 and 9.
[r] P. 169. lin. 8. supra.

been brought to its present situation by the present stream. Thus in going from Dalmalie to Inverary, at about five miles from the latter place, is a mountain stream, which runs over a tract of ground consisting of a mixture of earth and pebbles confusedly heaped together: the stream by undermining its banks washes away all the small or earthy particles, and the pebbles remain separate in the bed of the stream.

I have observed the same thing in many parts of South Wales and the adjoining counties of Hereford &c. in situations where not even a brook appears ever now to travel: and again the same fact is observable in many parts of Dartmoor, where there are no traces of a water course; and where indeed it is difficult to conceive that even a torrent can be ever formed, in consequence of the porous nature of the granite forming the substratum.

A stronger instance of the fact in question than those I have just mentioned occurred to me in Devonshire. One of the roads from Ashburton to Buckland passes between two rounded hills, on the top of each of which is one of those craggy summits called tors: the surface of each hill is more or less covered with fragments of the same character with the rock at the summit; but the summit on the right hand side of the road is the common granite of Dartmoor; while that on the left is a hard dark grey rock, called *dunstone*, penetrated by irregular veins of yellowish white quartz. The compound seems to me to be a compact form of the schist incumbent on this part of Dartmoor;

its substance being perhaps an intimate mixture of quartz and tourmaline. The low bank, which flanks a part of the road on the right hand side, exposes to view a section of the hill, and presents a confused mass of granitic gravel, partly consisting of angular portions of a granite resembling that of the contiguous summit and of the fragments scattered on the surface, and partly of a meagre loam apparently derived from the same granite completely broken down. It is of importance to mention, that the character of this gravel is so very distinct from that of the *grouan* or disintegrated granite of Dartmoor, that, had I not been aware of the mistakes that have sometimes arisen from the resemblance between the two, I could not have been deceived. And with respect to the origin of this gravel, as there is no evidence of any rivers or even torrents occurring in this situation, it must have been derived either from the gradual accumulation of the disintegrated granite of the hill on the surface of which it rests, or it was the effect of some sudden and powerful rush of water: of which two probable causes, although I admit the force of Dr. Mac Culloch's reasonings respecting the disintegration of granite, I prefer the latter: for on the one hand the gradual disintegration would have probably produced upon the whole a more regular and smaller grained gravel; and on the other hand the action of some rush of water is so naturally suggested by the appearances on the spot, as to lead one to prefer the application of such a cause.

But the most remarkable instance of scattered

boulders I have ever met with is in a narrow valley of the chalk downs on the borders of Berkshire, near a seat of Earl Craven's, called Ashdown Park. The surface of this valley, which separates a wood from an elevated platform of chalk that rises immediately from it by a steep ascent, presents the appearance of the ruined pavement of a gigantic edifice, being covered with numerous masses of that hard-grained sandstone, detached fragments of which are so common on the chalk downs of this part of England, where they are familiarly known by the name of *grey weathers* and *Sarsden stones*. The size of the fragments occupying the valley is commonly from three to five feet in length, by half that breadth and depth; but they are occasionally much larger. They lie scattered in an irregular manner, and partially imbedded in the soil: they are still so numerous as to render the road inconvenient even to a foot traveller; but evidently have once been much more numerous; for the wall of Ashdown Park is constructed of stones of the same kind, which were of course not brought from any other source.

The general appearance of the surface of this valley must, according to Saussure's description, correspond with that of the plain of Crau, near the lower part of the course of the Rhone: but if there is a difficulty in supposing the plain of Crau to have been the work of that river, there is a still greater difficulty in referring the present state of this chalk valley to the operation of any similar agent; for the existence of a river in the neighbourhood of it may be almost considered as a

physical impossibility, since the heaviest rains sink almost immediately into the soil; so that the only means of obtaining a permanent supply of water for the use of the flocks frequenting these downs is by the formation of artificial tanks; one of which has been excavated in this very valley. On the same principle there is no cause now acting which could produce those projecting fingers or tongues of land so characteristic of the skirts of the chalk downs, and the accompanying shallow ravines or indentations, by which those tongues are separated from each other; which, if they are referable to any cause independent of and subsequent to original formation, appear to have been effected by the action of powerful torrents.

It is worthy of remark, that not a single boulder, if I remember rightly, occurs on the acclivity of the chalk which bounds the valley above mentioned; nor are there to be found more than a very few scattered masses on that part of the platform of chalk immediately adjoining it. It was after a long walk with a friend over the neighbouring downs, during which the mind had been already carried back to distant ages by the vestiges of Roman roads and camps, and the remains of Druidical constructions, when we suddenly and unexpectedly came in view of this still more ancient scene of ruin; and I never can forget the awful impression which it instantaneously occasioned.

CHAP. XIX.

On the fossile Bones contained in certain calcareous Caverns of Germany; and also in the Clefts of the Rock of Gibraltar.

THE phenomena referred to in the title of this chapter are evidently of a similar class with those described in the two preceding chapters; for the fossile bones alluded to in the present instance must have been deposited, in the situations where they are now found, subsequently to the deposition of the most recent of the regular strata. But it is not necessary for me to enter into any detailed account of the phenomena in question; nor could I conveniently give such an account, without transcribing whole papers that have been written by Cuvier for the same purpose; which may be found in the Annales du Muséum. I shall content myself therefore with stating, from that source, such facts as bear upon the object of the present volume.

Of the bones met with in the caverns of Germany, at least three fourths belong to two distinct species of bear, neither of which is known now to exist: of the remaining bones, some resemble those of the pole-cat, and hyena, of the Cape of Good Hope; and Cuvier met with one jaw-bone from these caves, which, if to any living species, he thinks is referable to the jaguar, or great spotted panther of South America: but he says, that the greater part of the bones belong to species not known now to exist; all of them belong to spe-

cies of a very different climate from that of Germany: and yet there is strong evidence from the entire state of the bones, and from other circumstances, that the animals to which they belonged must have formerly inhabited and died quietly in these retreats.

The bones found in the clefts of the rock of Gibraltar, and also in rocks of a similar character near Montpellier, and at Nice, in Corsica also and along the coast of Dalmatia, belong principally to hares and other herbivorous animals: but some of them are not referable to any known animal.

It is stated by Cuvier, and the fact cannot fail to strike a reflecting mind, that the fossile remains of the elephant, rhinoceros, horse, buffalo, and tapir, which are species very common in beds of gravel, &c. never occur in the caverns above described: nor do those caverns even contain any of the organic remains found in the clefts of the rock of Gibraltar, &c. though the rocks both of the caverns and clefts appear to belong to the same formation[s]. And, reciprocally, the bears and tigers of the caverns do not occur either in depositions of gravel, &c. or in the clefts of the rocks of Gibraltar, &c. The hyena, Cuvier adds, is the only fossile animal of the caverns which has yet occurred in a different deposition; and that deposition is alluvial.

[s] From specimens which I have seen of each of these rocks, they appear to be the metalliferous compact limestone.

I have thus concluded the examination of the regular strata; and of those accumulations of gravel, &c. which, whatever may be their absolute date, have evidently been deposited subsequently to the strata themselves: and, though I have not judged it necessary to make the direct appeal at each step of the examination, I think the reader may draw the conclusion for himself, that no consistent theory of the earth can be deduced from the internal evidence afforded by the phenomena of geology hitherto considered.

I proceed now to examine the effects of those existing causes which, to a greater or less extent, are constantly producing changes on the earth's surface.

CHAP. XX.

On the Changes produced on the Surface of the Earth by the Action of Rivers; including the disintegrating Effects of the Atmosphere and of Mountain Torrents.

THEY who have only contemplated the phenomena of even the largest rivers of our own island, could have no adequate idea, from mere experience, of the effects produced by the mighty waters of such rivers as the Ganges, or even as the Rhone. The Thames, for instance, rising almost imperceptibly from its tranquil spring, flows through a great part of the year within its na-

tural channel; and though during the rainy season it may extensively overflow the neighbouring country, yet in its passage it neither disturbs the surface of the ground, nor does it seem to deposit upon it more *alluvion* than is sufficient to fertilize the soil from year to year: certainly at least in the neighbourhood of Oxford, where long winter floods almost constantly occur, the gradual accumulation of this alluvion, if it takes place at all, does not seem capable of being measured by any definite length of time: for the turf, in many even of those parts which are most liable to such an accumulation, rests immediately on the original substratum of gravel; which clearly would not have been the case, had the annually deposited alluvion much exceeded in quantity that which is required for the purpose of vegetation.

But if from this comparatively tranquil state of things the reader can in imagination transport himself among the elevated vallies of an alpine region; and can trace from thence the desolating course of a thousand tributary torrents, whose united waters are constantly conveying those particles by which the larger rivers of the subjacent plain are found to elevate the level of their own channel and of the surrounding country, so that finally even the boundary of the ocean itself is straitened by the accumulated soil; he will at once be compelled to allow that rivers are among the most extensive and powerful of those causes by which the surface of the globe is altered; and will be inclined to admit the probability of Dr. Hutton's proposition, that the materials of even the

natural strata of this earth have been originally prepared by similar agents.

In investigating the history of rivers I propose first to examine the circumstances of their origin; and as the nature of the present inquiry excludes in a great measure the consideration of smaller rivers, I shall not enter into the history of subterranean springs, from which such rivers often take their rise, but restrict myself to the origin and effects of those mountain torrents, to which, as to their immediate source, all the larger rivers of the world can be directly traced. It will be perfectly in the order of this inquiry however to examine previously to what extent, and in what manner, the atmosphere contributes towards the loosening and disintegration of the strata in those elevated regions, from whence these torrents have their source: for, independently of that action of the atmosphere, the mere mechanical force of the torrents themselves would be incapable of producing any of those tremendous effects, which render them so justly an object of terror to those who have once witnessed their violence. Against rocks, for instance, the structure of which is sufficiently compact to withstand the attack of any common violence, and whose composition is capable of resisting the chemical action of air and moisture, we see that the whole force of the ocean is, through ages, exerted in vain; and on this principle the line of coast in many parts of the world remains unaltered after a lapse of twenty centuries.

The Dean of Westminster, in describing the track of Nearchus's fleet along the gulph of Persia,

has an observation which tends to support the above opinion. "I now beg leave," he says, "to notice that the pilot on board Nearchus steered exactly the same course as Mac Cluer's Karack Pilot two thousand years afterwards; so durable is the stamp that nature has set upon this coast[t]." And although some of those promontories which have stood the shock of ages may hereafter be thrown down, it will only be in consequence of the wearing away of the surrounding rocks, from which they project, and by which they are in part supported. And so, there can be no doubt, were all the strata of an alpine region of a similarly compact structure and equally impervious to the chemical action of the atmosphere, the mountain stream, however impetuous its course, would throughout retain its transparency unclouded by a particle of earthy matter. But here, as in every other province of nature,

"The world by difference is in order found:"

for were all the strata of a soft substance, the mountains would have long ere this been levelled; and how then could rivers have continued to flow? or if they were altogether of an indestructible nature, the turbid waters of the Nile and of a thousand other fertilizing rivers would become transparent, and Egypt itself be rendered as barren as its neighbouring deserts.

The effects produced on rocks by contact of

[t] Voyage of Nearchus, p. 429. Vide also Periplus, part i. p. 73, and p. 130.

the atmosphere are partly dependent on the nature of their composition, and partly on their structure. What are the chemical changes produced in the former instance it is not perhaps easy to find out, nor is it in the present instance material to inquire: we may be content with the knowledge of the fact, that by exposure to the air the surfaces of many rocks become discoloured, and their consistence impaired to such an extent that they crumble on the slightest touch: and as this alteration often takes place more rapidly at their angles than in any other part, hence are produced those rounded masses of rock, the origin of which in the case of the granite tors of Cornwall, Dr. Mac Culloch has so ably illustrated in the last volume of the Geological Transactions. This disposition to a concentric disintegration in granite has been also noticed by Dolomieu[u]. And it is Daubuisson's opinion, that concentric disintegration is always the result of the action of the atmosphere; and that, as in the rusting of iron, this action will penetrate from the exterior many feet into the substance of basalt; but is not found to have taken place in the interior where the exterior is sound[x]. The general truth of the last mentioned fact however I have reason to doubt.

The disintegration of rocks as depending on structure is most easily traced in schists of various kinds; in some of which there is a disposition to separate, upon the slightest force, into fragments,

[u] Dolomieu, Iles ponces, p. 461.

[x] Daubuisson, p. 117, 118.

the surfaces of which are nearly parallel to each other; in others there is a disposition to separate, upon an equally slight force, in almost every direction. But there are many other rocks in which there are natural but less obvious planes of separation, which, though invisible to the naked eye, are detected by the effect produced upon them in consequence of violent percussion: and it must be in the recollection of every practical geologist, that many rocks, the larger masses of which appear to be of a perfectly compact texture, readily fall, under the application of the hammer, into fragments of nearly as regular a form as the rhomboidal fragments of a crystal of calcareous spar; and probably from a modification of the same cause, a crystalline arrangement, that is, of their particles.

With respect to the fact and extent of disintegration, Saussure states, that in the highest Alps, as in tracts of level country, many of the rocks are subject to complete decay from the action of the atmosphere[y]. Thus, near Montanvert, and among the strata at the foot of the chain of Mont Blanc, he met with a rock, consisting of rhomboidal or polyhedral masses so slightly united together, that the concussion of the air occasioned by the firing of a pistol would bring down many of them at a time[z]. Phenomena of this nature, though very different in degree, must be familiar to every one who has travelled much even among the mountain scenery of this island: and as cases in point I

[y] Saussure, tom. ii. p. 272. [z] Ibid. tom. iii. p. 6.

may mention the accumulation of broken laminæ of schist at the foot of Mam Tor in the Peak of Derbyshire; and a similar accumulation at the foot of Skiddaw: in both which instances I believe the *débris* of the mountain has in a great measure been the effect of *weathering* (as it is expressively called); the laminæ of the schist contracting in their dimensions during the dry season, and then necessarily detaching themselves; and in wet or frosty weather being separated by the insinuation of watery particles, or by the expansion that takes place in the congelation of those particles.

From effects like those above described it would appear, that in the course of ages mountains may be completely disintegrated: but the progress of disintegration in many instances may be arrested by means of vegetation. Thus Dolomieu says, that the inhabitants of Lipari suffer the ejected volcanic cinders to remain uncultivated till they become covered with herbs and brambles; which by the interweaving of the fibres of their roots form a kind of support for the soil, and thus afford a barrier to the action of the rain and torrents[a]. A similar effect is produced in Tibet, against the action of the wind, by a very different process. The air of Tibet being extremely dry, the dust is often very inconvenient to the husbandman; and it is therefore a practice in that country to cover the low lands with water immediately on the approach of winter: for this water, by freezing, incases the surface of the vallies with a sheet of ice,

[a] Dolomieu, Iles de Lipari, p. 74.

and prevents their being stripped of the soil by violent winds[a].

De Luc has an observation to the present purpose. Moveable sands, he says, are fixed by particular plants growing on them[b]; *heath* serving to attach vegetation to a sandy soil, as *moss* to a rocky surface[c]. Nor is it easy to conceive, how the weather, where permanent vegetation has been once established, can ever affect the surface. The Roman road called the Ridgeway, which passes over a part of the chalk downs of Berkshire, and which, I believe, was never paved, remains unaltered after 1600 years; nor is there any reason to suppose it will ever be affected by the action of the atmosphere: and by analogy the surface of the chalk downs themselves, and the similar bosoms of Dartmoor, would remain for ever, as far as the action of the atmosphere is concerned, in their present state.

But when the disposition of the surface of the ground, and the nature of the strata upon the summits of mountains, are such as to admit of large accumulations of water, it sometimes happens that the mere pressure of the water in these elevated reservoirs suddenly bursts their barriers, and in a moment buries the subjacent valley in a mass of ruins. De Luc's brother asserts, that a single momentary inundation of this kind in the high Alps transports such a quantity of *débris* as at once to change the appearance of a considerable extent of

[a] Turner's Tibet, p. 329.

[b] De Luc, Lettres, tom. iii. p. 68. [c] Ibid. p. 423.

ground, carrying away whole forests[d]. The occasion of such inundations and their effects are described more particularly by Saussure, who says, that in some parts of the Alps, where the rocks are composed of easily disintegrating schist, dreadful accidents occur from accumulations of water in natural basins or cavities of this schist: for when these accumulations of water have reached a certain height, they all at once burst the crumbling sides of their reservoirs, and descend, with a terrible impetuosity, in the state of a liquid mud mixed with fragments of slate and other rocks. The impulsive force of this half liquid half solid mass is indescribable: it tears down rocks, overthrows buildings, roots up the largest trees, and desolates the fields by excavating deep ravines, and covering the surface to a considerable extent and depth with silth, and gravel, and fragments of rocks[e]. Torrents of this kind, which are so frequent in the Alps as to be known there by the generic name, "Le Nant sauvage," rarely last more than an hour; and those of my readers who recollect the tremendous effects produced last year by the bursting of a mere vat in a public brewery, will have no difficulty in giving credit to the foregoing description of Saussure.

These torrents are representations in miniature of that *débacle*, or vast rush of water, by which Saussure supposes the enormous blocks of granitic and other rocks, which are found almost every

[d] De Luc, Lettres, tom. v. p. 401, & 414.

[e] Saussure, tom. ii. p. 205.

where in the neighbourhood of the Lake of Geneva, were formerly transported thither from the high Alps: and he was easily induced, from the size of the fragments which these momentary torrents roll forwards in their course, to attribute to this debacle the force requisite for the effect above described. In July 1751, after a winter remarkable for an unusual fall of snow, a great part of a mountain, having three lakes at its summit, gave way, and fell with a tremendous crash at Servoz, near the valley of Chamouni, sending up into the air a cloud of dust resembling smoke. The cubic contents of the masses which fell on this occasion amounted collectively to three million toises[f]. The inhabitants of the neighbourhood supposed a volcano had broken forth.

I am not certain whether the following facts are referable to a cause similar to that above described; though I believe they are: but at all events, from the illustration they afford of the effects produced by the disintegration of the strata, I may fairly give them a place in this part of the present chapter.

Near Chambery in Savoy, between Mont Grenier and a village called Mians, is a plain, of the area of about a league, covered with small eminences of sand from twenty to twenty-five feet high: this spot is called "les Abîmes de Mians;" and there is a note in an old missal in a neighbouring monastery, which says, that in 1249 a great part of the mountain fell down and overwhelmed

[f] Saussure, tom. ii. p. 212—218.

a priory and several small hamlets that stood in this plain. Saussure adds, that this is probable, for you may see an enormous gap in the mountain exactly over the plain; and he supposes that the large fragments brought down on that occasion became nuclei, round which torrents have gradually accumulated sand, &c.: and he says, besides, that in many instances you may, by removing the soil and grass, discover the subjacent fragments. It is clear, he adds, that their formation was subsequent to the general revolution which produced the *débris* of the Alps; because neither on their surface nor within them are found any fragments corresponding with the general debris, but only fragments of the particular rock from which they appear to have been formed[g].

I am indebted for the following account to the Rev. C. Hue, who was an eye-witness of the scene which he describes. Immediately after passing on the north of the Lake of Lauertz, in travelling from the east, the ruins of the Rossberg are seen scattered up and down the valley situated between that mountain and the lake. These ruins, consisting almost entirely of fragments of pudding-stone, some of which are of an enormous size, cover an extent of surface of from six to eight square miles. Many of these masses have been driven across the valley to a considerable distance up the sides of the opposite hills, the road passing among the fragments over a broken and irregular surface. At some distance, on the north, the

[g] Saussure, tom. v. p. 27.

Rossberg itself is seen, a wild and barren mountain; without a tree, or shrub, or the least trace of vegetation from its summit to its base: but there are several fertile spots, and a few cottages in the intervals of the rocks that are dispersed throughout the valley. Some of the inhabitants of Arth in that neighbourhood, who had witnessed the melancholy catastrophe, informed Mr. Hue, that the ruins he had just passed had been occasioned by the sudden fall of a large portion of the Rossberg in September 1806; the fragments of which, rolling down with a dreadful noise, and an astonishing rapidity, in a very few minutes overspread the valley, and completely buried the village of Goldau situated at the foot of the mountain. Above four hundred persons, inhabitants of that district, lost their lives on this occasion.

But, quitting the consideration of occasional and momentary inundations, let us examine the history of those torrents, which to a greater or less extent are in action in mountainous tracts of country through the greater part of the year; and whose final effects contribute in an infinitely greater degree towards the disintegration of the strata: for, though not disposed to agree with Dr. Hutton in the opinion, that the main or longitudinal vallies of an alpine district have been excavated by the rivers which flow through them, I believe it cannot be denied that most of the transversal vallies are in a great measure the work of their several streams.

The inhabitants of the southerly part of this island, who often witness a whole day's rain with-

out any sensible increase in the river of their district, would be utterly unable of themselves to form an idea of the streams, the rivers I may say, which are absolutely created in a mountain district by the fall of less than an hour's rain. For myself, I never can forget the surprise I felt, when in returning from a mine near Tyndrum in the Highlands I found my passage intercepted by a rapid river some yards in breadth, in a part, where, in my way to the mine, I had not only not crossed any even the smallest current, but had not observed the track of any regular water-course: and when the distance at which this part of the river must have been from the torrent that gave rise to it, and the slight degree of inclination on which it was now running, were compared with its rapidity and force, the mind of the most prejudiced observer must have been disposed to hesitate, at least, in denying the effects attributed to the action of rivers by the Huttonian theory.

But though the mountain stream rolls forward to a considerable distance many of the smaller fragments which its parent cataract tore off in its descent, yet the larger masses remain for ages imbedded in or resting on the ground where they are first lodged: and admitting even that they may in time be propelled forwards by repeated subsidence of the level of the ground on their lower side, and may thus ultimately be conveyed to the most distant point; yet as their progress must be necessarily extremely slow, and as during the whole course of it they must be constantly subject to attrition, it seems clear that their size

must be continually diminishing; and that they can never reach the level tract of country through which the river will soon flow, without being reduced in their dimensions greatly below those enormous masses which Saussure describes as scattered in profusion round the Lake of Geneva, and far distant also from any water-course. But facts themselves tend to support the opinion just expressed, as we shall see when we come to examine the progress of a river after it has fairly quitted the defiles of the mountain. At present I shall consider the opinions of Saussure and Pallas respecting Dr. Hutton's hypothesis, that vallies in general, the larger as well as the smaller, have been excavated by the rivers that run through them.

Saussure then, notwithstanding his conjecture, that vallies in mountain groups may have been originally formed by some simultaneous cause, as elevation or depression, and that the partial filling up of these vallies with the *débris* of the surrounding rocks has been to a certain extent effected by that great debacle to which he so often alludes, yet with his known candour admits, that the *present* state of vallies with the arrangement of main and tributary streams is owing to the erosion of rivers[h]. Thus, he says, in looking from an eminence on the group of hills called Mont-Ferrat, which in part surround Turin, it may easily be perceived that the innumerable vallies which furrow those hills in every imaginable direction are

[h] Saussure, tom. iv. p. 105.

the work of streams arising from rain; for they have all a considerable degree of inclination, are narrow towards the upper extremity, and widen as they approach the plain[i].

On another occasion he says, he has often observed that the form of vallies among mountains has been determined by the softness of the rock of which they occupy the place[k]. Again he observes, that the lateral vallies of that tract of country, through which the Rhone runs previously to its entrance into the Lake of Geneva, do not appear to have been cut out by the sea: they evidently appear to have been formed, or at least enlarged, by the rivers which descend from their upper terminations[l].

Pallas supports Dr. Hutton's hypothesis in a still more decided manner than Saussure; for in speaking of that part of the Altaïsch chain which separates the Russian and Chinese empires, he says, that all the salient angles in the vallies of that chain are formed by the numerous rivulets and torrents, occasioned continually either by rain or by the melting of snow: and he adds his persuasion that, in general, mountain vallies, however large, have been formed by these agents; and that the mountains intersected by them have once been much higher. He even thinks that vallies at a distance from mountains, and near the sea, have been frequently formed in the same manner; and, more than this, that those large vallies or basins

[i] Saussure, tom. v. p. 184.
[k] Ibid. tom. vi. p. 265.
[l] Ibid. tom. viii. p. 9.

surrounded by mountains, which occur in various parts of the world, have also been sometimes thus formed[m].

But then neither Saussure nor Pallas suppose that vallies are in all instances the entire work of the rivers which intersect them. Thus the former of these philosophers, in describing the valley through which the Rhone flows for about fifty miles previously to its entrance into the Lake of Geneva, says, that the forms of the mountains on its opposite sides do not correspond; nor is there any other evidence that this great valley has been cut out by water, either of rivers or of the sea; no marks of erosion, no corresponding angles[n]. And Pallas also, in speaking of a particular valley in the exterior chain of the Altaïsch mountains, which is washed by only two or three small rivers, says, that it is superficially covered with soil under which is a bed of gravel and pebbles of all sizes; which is a proof, he adds, that this valley was anciently washed by waters much more considerable than at present; and he says, that many other vallies situated among high mountains are of the same nature[o].

To take an instance from our own island, on the southern coast of Devonshire, which fell under my observation last summer: if we even cursorily view those nearly contiguous combs or vallies in which Sidmouth, Axmouth, and the village of Branscomb are situated, all of which open towards the

[m] Pallas, tom. iii. p. 256.
[n] Saussure, tom. viii. p. 9.
[o] Pallas, tom. iii. p. 265.

sea, we shall find, that the two former are very wide towards the sea, and become upon the whole narrower as they recede from it; whereas the last mentioned comb communicates with the sea by a very narrow passage, which is little more than a defile. Yet, as the strata of all these vallies have a remarkable similarity, both in their nature and arrangement, it is difficult to conceive, on the supposition that these vallies have been excavated by the streams which intersect them, why the form and the extent of the mouth of Branscomb should be so very different from the others.

But to return to the character of the alluvion deposited by rivers, and to other points of their general history, we shall find that even comparatively near their sources the size of the particles deposited is not very great. Thus though, according to Saussure, the bottom of the valley of the Rhone between Aigle and the entrance of the river into the Lake of Geneva appears evidently to have been deposited by the river, (for the valley in this part is perfectly horizontal, and composed of parallel beds of sand and silth, but little elevated above the level of the river;) yet from the very nature of these beds it is also evident, that only the *finer particles* of the debris of the strata have been brought down[p]. Again, in speaking of the passage between the extremity of the chain of Jura and the Vouache, through which the Rhone runs after having quitted the Lake of Geneva; and of the passage also between the mountains called the

[p] Saussure, tom. i. p. 91.

Greater and the Lesser Saleve, through which the Arve runs a little before its junction with the Rhone; Saussure says, that the similarity of the stratification on both sides is so exact as to shew that the strata have been worn through by water: but he adds, that these passages are not attributable to the usual action of the Rhone or Arve, but to some mighty current, which issued from the basin of the lake, when its waters were at a much higher level; and of which there is a farther proof in the great blocks of granite and slate which are scattered about the neighbourhood, and are far beyond the size which the present current could even move, much less transport to any distance [q]. The river at least has made no alteration in this passage during two thousand years; for Saussure, in describing the narrow road-way which the extremity of the Jura leaves between itself and the bed of the Rhone, gives the following quotation from Cæsar: "Iter angustum et difficile inter montem Juram et flumen Rhodanum, vix qua singuli carri ducerentur; mons autem altissimus impendebat ut facile perpauci prohibere possent [r]."

Major Rennell, in his memoir on Hindostan, has made a somewhat similar observation to that of Saussure above mentioned, accompanied also with an historical reference of a still more interesting nature. He says, that when Alexander's fleet arrived at the conflux of the Hydaspes and Acesines, the rapid and troubled stream formed by

[q] Saussure, tom. i. p. 208.

[r] Cæsar De Bello Gall. lib. i. cap. 6.

their confluence dismayed the whole fleet, and proved fatal to some of the large ships; and a similar description of the conflux of the Chelum and Jenaub (which there are strong grounds for supposing are the Hydaspes and Acesines of antiquity) is given in Shereffedin's Life of Timour, who passed that conflux in the year 1398, nearly at the same season at which Alexander had passed it. Major Rennell observes, that the identity of the passage of Alexander and of Timour is most pointedly marked out by the steep and rocky nature of the banks by which the abovementioned rivers are pent up, and by which, consequently, a rapid and troubled stream is formed at their confluence[s]. The Dean of Westminster, in a similar manner, by identifying the position of an island in the Hydaspes, ascertains that the progress of Timour was opposed by the native prince of the country, at the distance of sixteen centuries, almost in the very spot where Porus had encountered Alexander[t].

But it is at the same time true, that rivers even of a moderate size, and long after they have quitted the mountains, do in some instances destroy their banks to a considerable extent. Thus the Severn, a few miles below Gloster, has, within the memory of man, worn away a considerable portion of its right bank, so as to form that precipice near Westbury, which is called Garden Cliff, with a considerable depth of water on that side of its channel; and I remember, when at the spot a few

[s] Rennell's Hindostan, p. 96.

[t] Voyage of Nearchus, p. 95.

years since, to have seen the track of a cart-road, which had been abruptly cut off in consequence of the gradual undermining of the cliff. Exactly in the same manner, according to Pallas, the Oka, a tributary river of the Volga, is gradually undermining a hill on which the city of Mourom is situated[u]; and it is worth noticing, that in each of the two instances just mentioned, the bank of the river consists in part of rock marl, a stratum which is very easily disintegrated. Major Rennell observes, that it is no new thing for the rivers of India to change their course and place of confluence[x]: thus the Soane, which once joined the Ganges near Patna, now joins it twenty-two miles from Patna[y]; and the Cosa also once joined the Ganges forty-five miles lower down than it does now; and the Burrampooter has varied its course still more[z]. And it is stated by Pallas, that the underminings of the Volga are continually changing the face of the adjacent country[a].

But in the case of small rivers in a level tract of country, and in latitudes not differing much from our own, the channel remains the same for ages: thus between Islip and Woodstock, near an inn called Gibraltar, the river Cherwell runs almost immediately under a soft limestone cliff on one side, the ground rising generally on the same bank in that neighbourhood; while on the other side

[u] Pallas, tom. i. p. 49.

[x] Rennell's Hindostan, p. 53.

[y] Ibid. p. 50.

[z] Ibid. p. 53.

[a] Pallas, tom. v. p. 228.

there is an almost perfectly level meadow of considerable extent: but there is a very satisfactory local proof that the river is not in progress of excavating the bank on one side, or of extending it on the other: for there is a very ancient bridge across this part of the river, between the extremity of which and the cliff there is no more space than is sufficient for a carriage-road. I have frequently observed similar facts.

With respect to the mode in which rivers operate in excavating their banks Major Rennell says, in describing the action of the Ganges, that commonly there is found on one side of the river an almost perpendicular bank (more or less elevated above the stream, according to the season), with deep water near it; and on the opposite side a bank shelving away so gradually, as to occasion shallow water at some distance from the margin. So, in the case of the Westbury cliff above mentioned, the Severn, in the act of undermining the right bank (which forms that cliff), is thrown off at an angle towards the opposite shore; where, the velocity of the stream being checked, and a back water formed, the earthy particles, held in suspension by the river, are deposited; by which that side of the channel is gradually filled, and a quantity of new land is formed, which, in the instance now under consideration, is seen in the form of a flat meadow opposite the cliff of Westbury. In the case of the Ganges, Major Rennell says, that where the current is remarkably rapid, or the soil uncommonly loose, such tracts of land are swept away, in the course of one season, as would astonish those

who have not been eye-witnesses to the magnitude and force of the mighty streams occasioned by the periodical rains of the tropical region. This necessarily produces a gradual change in the course of the river; what is lost on one side being gained on the other by the mere operation of the stream [b].

During eleven years of Major Rennell's residence in Bengal, the outlet or head of the Jellinghy River was gradually removed three quarters of a mile further down; and by two surveys of a part of the adjacent bank of the Ganges, taken about the distance of nine years from each other, it appeared that the breadth of an English mile and a half had been taken away. This, however, was the most rapid change he noticed; a mile in ten or twelve years being the usual rate of encroachment, even in places where the current strikes with the greatest force [c]. It is stated by the Dean of Westminster, in his Voyage of Nearchus [d], that the great city of Lahore, formerly the centre of an immense commerce between Dehli and the country about the several streams of the Indus, began to decline in consequence of the Ravee, on which it is situated, having changed its course, so as to run at some miles' distance.

Two causes, Major Rennell observes, very different from each other, occasion the meandering courses of rivers: the one, the irregularity of the ground through which they run, which obliges them to wander in quest of a declivity; the other,

[b] Rennell's Hindostan, p. 261.

[c] Ibid. p. 263.

[d] Voyage of Nearchus, p. 86.

the looseness of the soil, which yields to the friction of the border of the stream. The meanders in the first case are of course as digressive and irregular as the surface they are projected on; but in the latter they are so far reducible to rule, that rivers of unequal bulk will, under similar circumstances, take a circuit to wind in, whose extent is in proportion to their respective breadths. The windings of the Ganges in the plains are doubtless, he says, owing to the looseness of the soil: and he thinks the proof of it is, that they are perpetually changing; which those originally induced by an inequality of surface can seldom or never do. And though it is often stated, that the course of rivers becomes more winding as they approach the sea, Major Rennell believes this only happens in the case of such as take the latter part of their course through a sandy soil [e].

But the change produced on the surface of the earth by rivers is not confined to the mere alteration of their course: the earthy particles which such rivers bring down with them are constantly elevating the level of their channel; and, from the frequent change in their course, a similar elevation is finally produced in the level of the surrounding country; which is further aided by the additional quantity of alluvion brought down and distributed during their periodical inundations. This effect is so obvious, that it could not escape the notice of the earliest natural philosophers. Thus Cicero

[e] Rennell's Hindostan, p. 264.

says, "Ægyptum Nilus irrigat, &c.; Mesopotamiam fertilem efficit Euphrates: in quam quotannis quasi novos agros invehit[f]." And many of my readers, though they have been directing their attention to higher subjects than geological speculations, may remember that Herodotus, in acknowledging that the greater part of Egypt has been the *gift of the river*, argues, that were the course of the Nile to be by any means diverted into the Red Sea, the channel of that gulph would probably in time be entirely obliterated from the same cause.

Pallas observes that the Volga, like the Nile, overflows its banks to a great extent (rising from twenty-five to forty feet above the edge of its banks), so that only the tops of the highest trees are visible[g]. And in another part of his works he says, that these inundations, no less than the undermining action of the river, are continually changing the face of the adjacent country[h]: correspondent to which statement is a fact mentioned by him in another volume, that the wood and trees brought down by the inundations of the Volga supply the neighbouring inhabitants with fuel[i].

But the quantity of alluvion brought down by even a river comparatively so small as the Thames is considerable. Derham, in a paper written from Upminster in Essex, says, "It is a practice

[f] De Natura Deorum, lib. ii. cap. 52.

[g] Voyages, 1793, tom. i. p. 64.

[h] Pallas, tom. v. p. 459.

[i] Ibid. tom. iii. p. 251.

among us, that where a breach would cost more to stop than the lands overflown will countervail, there to leave the lands to the mercy of the Thames; for these lands, gradually growing higher and higher by the additions of sediment, will in time shut out all except the highest tides of the river [k]."

It is stated by Major Rennell, if I remember rightly, that a glass of water taken out of the Ganges at the height of its inundation yields one-fourth of sediment. And Barrow, in his account of China, says, that the quantity of mud perpetually brought down by the Yellow River was found, by calculation founded on experiment, to exceed two million solid feet in an hour; and that in crossing this river at some miles' distance from the sea, in a part where it was three quarters of a mile broad, and was running at the rate of seven or eight miles in an hour, the water was as thick and muddy as if the heaviest torrents of rain had just descended; whereas there had not fallen a shower for many months [l].

If now we view some of the larger rivers of the world near the point where they are about to communicate with the sea, their effects in altering the surface of the earth will be still more visible. Pallas says, that the Volga, at its entrance into the Caspian Sea near Astracan, forms by its numerous branches a multiplicity of islands, and enters that

[k] Phil. Transact. 1710, p. 483.

[l] Barrow's China, p. 492 and 511.

sea by no less than seventy mouths[m]: and it is stated by Mr. Turner, that when the Burrampooter has joined the Ganges, they run together a short course under the name of the Megna, intersecting by numerous streams a large territory called the Sundrabunds, famed for the beauty of its groves. From these groves the city of Calcutta is constantly supplied with fuel, as from an exhaustless mine; the growth of one season, such is the quickness of vegetation, fully replacing the consumption of the former year[n]. Major Rennell says, that some of the islands formed by the united streams of the Ganges and Burrampooter, rival, in size and fertility, the Isle of Wight.

Before I conclude this part of the subject, I shall briefly describe the process by which the Deltas of large rivers are extended on that side of them which is towards the sea. The progress of extending the Delta of the Nile is thus described by Denon: A north wind blowing against the mouth of the Nile about August, the contending waters of the river and the sea thus throw up a bank or island of sand, which has the effect of dividing the river into two branches. The eddy formed by this island throws back on the beach the sand that has been brought down by the river; and thus at length one of the lately formed branches is blocked up, the island becomes entirely connected with the main land, and the remaining branch repeats the

[m] Pallas, tom. v. p. 228 or 459.

[n] Turner's Tibet, p. 299.

process, a new island being formed at its mouth, and so on. The newly formed land first produces three or four kinds of sea-weed, round which the sand throws itself up in heaps; the subsequent decay of this weed furnishes a manure which favours the vegetation of reeds; and these reeds give a greater elevation and a greater solidity to the soil: the date tree now appears, and by its shade prevents the sudden evaporation of the moisture; till at length, the Delta having by degrees been more and more extended, forests and palm trees are seen at a league's distance from the shore, on spots which were once covered by the sea °.

It is stated by De Luc, that almost all the rivers which flow into the Baltic and the German Ocean, between the Scheldt and the Oder, run, during the latter part of their course, through a district consisting of strata of marl and sand and clay. This original soil, which is very prevalent through Brabant, Westphalia, Lower Saxony, and all that part of Europe, is called *geest*, and is met with also in many of the islands of the Baltic. These sandy and marly strata being easily disintegrated, the rivers above mentioned bring down with them a great quantity of sand and clay, forming a more or less extensive tract of alluvial soil near their mouths. Such depositions are very commonly found in all this part of the coast; and, as they have a character very distinct from that of the original strata of the country, it is very easy to distin-

° Denon, vol. i. p. 110.

guish the line of separation. The occasional depth of this deposition is very considerable.

Besides the quantity of alluvion deposited at their mouths, rivers of course convey a certain proportion out to sea; and in some instances that proportion must be considerable. Thus Major Rennell, in speaking of the Irrabatty, or the great river of Ava, says, that the mouths of this river form an assemblage of low islands like those of the Ganges; and that the currents of these mouths are so powerful, and so disturb a ship's progress, as to render it impossible in the ordinary course of navigation to obtain a correct account of distances[p]. Currents like these must necessarily carry out with them a great abundance of suspended alluvion: for this is the case of comparatively small rivers. Thus the Rhone is constantly carrying alluvion into the Lake of Geneva.

Humboldt asserts, that the Gulph of Mexico is gradually filling up by the sand brought into it from the Carribean Sea on the south side, and from the numerous rivers that discharge themselves into it on every side; particularly from the Rio del Norte and the Mississippi. A great proportion of this sand is by the gulph stream thrown up along the eastern coast of that part of America; so that sand banks with shells have been found thirty miles in the interior: and hence the want of convenient ports for large shipping on this coast[q].

[p] Rennell's Hindostan, p. 39, 40.

[q] Humboldt, tom. i. p. 307.

The Gulph of Petchelee, into which the river of Peking discharges itself, was probably once much larger than it is now; and a great proportion of that part of China which adjoins it has apparently been formed by the sand thrown up from this gulph and the river which descends into it: for though the tide at the mouth of this river rises only nine or ten feet, it flows inland to the distance of one hundred and ten miles, and frequently inundates the whole country, the general level of which is not more than two feet above the surface of the river; of which not only the bed but also the substratum of the inclosing banks are composed entirely of fine sand, like that on the sea-shore. Moreover the deepest part of the wide Gulph of Petchelee does not exceed twelve fathoms; and the prodigious number of small sandy islands, just appearing above the surface, are said to have been formed within the records of history[r].

Connected with this part of the subject is another fact mentioned by Barrow, that a great portion of the enormous mass of mud that is perpetually brought down by the Yellow River, which, as has been before said, has been ascertained by calculation founded on experiment to exceed two million solid feet in an hour, is borne by a strong current from the Yellow Sea into the Gulph of Petchelee, where the stillness of the water allows it to subside[s].

The sea coast on the south of the province of Bengal is so shallow, from the accumulations of the

[r] Barrow's China, p. 492.

[s] Ibid. p. 492.

Ganges, as to have only one port, and that of difficult access, in an extent of three hundred miles [t]. So, in speaking of a lake described by Arrian at the mouth of the Indus, but not now existing, the Dean of Westminster says, "This lake is evidently no more than a bay, into which the eastern channel fell, and must be searched for in vain at the distance of twenty centuries, considering the nature of the river, and the accumulations at its mouth [u]." And in the same work there is a description of a similar circumstance which has taken place at the mouth of the Tigris [x].

From all that has been said it appears, that the sand &c. brought down by rivers does not only contribute towards elevating the land during the course of those rivers, but also towards forming extensive banks near the shore, and filling up sometimes even distant gulphs. But it also appears, from an examination of phenomena, that rivers do not act immediately in filling up the bosom of the sea, unless near the shore: in other words, that rivers, however rapid, soon deposit the earthy particles with which they are charged. Thus the Rhone, though it carries much alluvion into the Lake of Geneva, deposits all of it long before it issues from the Lake; for its waters pass quite clear out from thence, giving rise indeed to the following very interesting phenomenon in consequence. The Arve, at its junction with the Rhone, being fully charged and discoloured with

[t] Rennell's Hindostan, Introd. p. cxv.

[u] Voyage of Nearchus, p. 155.

[x] Ibid. p. 435—438.

earthy particles, while the Rhone is perfectly transparent, the waters of the two rivers, for some way after their junction, are discernible from each other[y]. And even in the case of the largest rivers Major Rennell observes, that the sea, though for a considerable distance discoloured by them, usually recovers its transparency at the distance of twenty leagues from the coast[z].

I proceed now to examine the nature and extent of the alluvion deposited by rivers.

It appears from what has been said above, that in that evidently alluvial tract of country between Peking and the mouth of its river, in the Gulph of Petchelee, neither a *stone* nor a *pebble* of any magnitude occurs: the whole, to a considerable depth, is *fine sand*[a]. And Major Rennell says, that from Lucknow to Calcutta, which is six hundred and fifty miles by the nearest road, is one vast plain[b], all which is probably alluvial matter, deposited by the river; for in another part he says, that in digging through the alluvion that has been accumulated by the Ganges down to the original soil, nothing is found but *sand* and *mud*: and neither in the delta of this river, nor at any point within four hundred miles of the sea, is there any substance in this alluvion so coarse as *gravel*[c].

The following sections of two decidedly alluvial tracts of country in different parts of Europe il-

[y] Saussure, tom. i. p. 12.
[z] Rennell's Hindostan, p. 266.
[a] Barrow's China, p. 491.
[b] Rennell's Hindostan, p. 63.
[c] Ibid. p. 268.

lustrate well the general character of alluvial beds. The first is taken from the Gentleman's Magazine, and is a section of the strata or beds penetrated in digging wells in the neighbourhood of Modena [e].

1. Rubble and ruins.
2. Compact soil.
3. Black fenny soil abounding with marshy reeds; barley straw, and a cluster of hazel nuts on an undecayed bough, were found in this stratum at the depth of twenty-six feet from the surface.
4. Alternations of white and black soil, with branches of trees having the bark entire.
5. A marl or clay, containing cockles.
6. Marshy ground, with reeds and leaves and branches.
7. Marl like N°. 5.
8. Marshy ground.
9. Marl or clay.
10. Marshy ground.
11. Soft sand mixed with gravel and cockle shells.

In the lower depth of the wells are found great beans, coals, flints, and pieces of iron: and at the first gush of the water leaves of oak, chesnut, bean-pods and millet are brought up.

The following account of the strata penetrated in the digging of wells &c. in the neighbourhood of Amsterdam is taken from Leibnitz [f].

	feet
Garden soil	7
Turf	9
Clay	9
Sand	8
Earth or mould	4

[e] Gentleman's Magazine, 1755, p. 396.

[f] Leibnit. vol. ii. part ii. p. 240.

Clay	10
Mould	4
Sand, on which the piles of the houses in Amsterdam rest	10
Clay	2
White gravel or sand	4
Dry earth	5
Moist earth	1
Sand	14
Sandy clay	3
Sand and clay	5
Sand with sea shells	4
Clay	102
Gravel	31
	232

All of these strata but the two last are probably alluvial; and if the two last are original strata, that which Leibnitz has called gravel is perhaps a disintegrated granite.

The history of the changes which are taking place with respect to *Lakes* is necessarily involved in the history of rivers; but, as the order of the subject would have been otherwise disturbed, I have hitherto avoided more than an incidental mention of them.

It is a fact which rests on historical evidence, that many lakes at present in existence were formerly much more extensive than they are now; and since all lakes are either temporary or permanent reservoirs of the rivers which flow into them, it is evident that they must also be, to a greater or

less extent, the receptacles of the alluvion brought into them by those rivers. Thus Saussure says, that the back-water occasioned by the entrance of the Rhone into the Lake of Geneva, aided by westerly winds, has thrown up so much sand to the east of the entrance of the river, that within the period of history a village, formerly situated on the very border of the Lake, has been separated from it by an interval of half a league: and within the space of fifty years an eye-witness, on whose fidelity he could rely, told him, that he had measured an extent of new ground half a league in length, and more than forty paces in breadth [i]. And it is observed generally by Saussure, that all the lakes he had visited are filling up on that side from whence they have their source; namely, in consequence of the deposition of the sand of the rivers that enter them from the mountains [k]. Thus the Lake of Nantua between Lyon and Geneva, he says, is evidently in the progress of filling up [l]: and the Lake of Thun forms also by its contraction large alluvial plains on its borders [m]: and between the Lakes of Brientz and Thun is a plain of a league in length, evidently of alluvial origin [n].

Pallas observes, that the Lake Baikal also, in the south-east part of Siberia, (which Lake compared with many others is an inland sea,) was formerly more extensive than it is now [o]. He then mentions the following inexplicable circumstance

[i] Saussure, tom. i. p. 9.
[k] Ibid. tom. viii. p. 2.
[l] Ibid. tom. vi. p. 209.
[m] Ibid. tom. vi. p. 226.
[n] Ibid. tom. vi. p. 230.
[o] Pallas, tom. iv. p. 407.

in its natural history. The sea dog, an animal which is not accustomed to advance into rivers to any great distance from their mouths, is found in the Lake Baikal, though situated almost in the centre of Asia, and at the distance of nearly a thousand miles from any sea; between which and this Lake the animal has never yet been seen [o].

But by far the most remarkable instance of this natural process is given by Humboldt in his account of Mexico. The valley in which the city of Mexico is situated, though more than five thousand feet above the level of the sea, is literally encircled by a chain of mountains: and it seems evident, that this valley is the bottom of a lake which once was spread over it, and of which the five comparatively small lakes, now occupying portions of it, some of fresh and some of salt water, are the remains [q]. About one tenth of the area of the Valley of Mexico (the whole of which equals a space of two hundred and forty four square leagues) is occupied by four principal lakes [q]. In 1520 Cortez describes two great lakes as existing in this valley; one of salt water, and having tides like the sea; (in which, however, it appears that Cortez was deceived, the appearance of tides having been owing to periodical winds blowing the water from the east to the west bank [r]:) the other, of fresh water. It was in the salt lake that Tenochtitlan the old city of

[o] Pallas, tom. iv. p. 413.
[p] Humboldt, tom. i. p. 121.
[q] Ibid. tom. ii. p. 106, and 193.
[r] Ibid. tom. ii. p. 132.

the Valley stood, and it was surrounded on all sides by water, having causeways leading to the main-land. At present the centre of the city of Mexico, placed on the site of Tenochtitlan, is four thousand five hundred yards from one of these lakes, and nine thousand yards from the other; so that the present city is placed entirely on *terra firma*, between the salt water and fresh water lake: and, from geological observations, it is probable, that these lakes had begun to diminish long before the arrival of the Spaniards in the sixteenth century[s].

In dry summers so small a quantity of water comes into the lakes, and there is always so great a degree of evaporation going on at that elevation, that the gradual lessening of the lakes is easily accounted for: and it evidently appears that the shallower parts, being gradually exposed in consequence of evaporation, become marshy grounds; which, being first drained by artificial canals, are subsequently cultivated[t]. The lessening of the lakes became much more rapid after the conquest: for the Spaniards every where destroying the trees, the shade of which had retarded evaporation from the surface of the soil, the retained moisture thus passed by infiltration into the lake[u]. Artificial drainage has also stopped the overflowing of the northern lakes of the valley into the southern; with respect to which inundations this remarkable fact is stated, that they periodically return about every

[s] Humboldt, tom. ii. p. 111, 108, 126, and 115.

[t] Ibid. p. 127.

[u] Ibid. p. 129.

twenty-five years [x]. The city of Mexico is scarcely four feet above the level of the neighbouring lake; and as the mountain streams are constantly elevating the bed of the lake by the sand they bring down, the level of its surface is constantly coming nearer the level of Mexico; and consequently the danger of inundation is increasing. Humboldt observes, that with the view of obviating a similar danger the Venetians have turned away from their lakes the Brenta and several other rivers which deposit sand in them [y].

It appears from what is above stated, that the Valley of Mexico was probably once entirely a lake. And many philosophers have been convinced of the general probability that some spots now free from water were once lakes. Saussure says, that he met with a flat basin of land in the valley of the Aar which he conjectures was formerly a lake [z]: and Major Rennell has the same conjecture respecting a very remarkable tract of land in India. The country of Cashmere (which has been called "The Paradise of the Hindoos," "the Garden of perpetual Spring") is an elevated valley surrounded by steep mountains. The soil of this valley, which is of the richest nature and of vast depth, is composed of the mud deposited by the Chelum; which originally occupied the whole valley in the form of a lake, until it opened itself a passage through the mountains. Major Rennell adds, that although the foregoing account has no living testimony to support it; yet history and tradition,

[x] Humboldt, tom. ii. p. 199.

[y] Ibid. p. 201.

[z] Saussure, tom. vi. p. 250.

and, what is yet stronger, appearances, have impressed a conviction of its truth on the minds of all those who have visited the scene, and contemplated the different parts of it. At the present day many small lakes are spread over the Valley of Cashmere, some of which contain floating islands [a].

So far am I from doubting, Major Rennell in another part says, the tradition respecting the existence of the lake that covered Cashmere, that appearances alone would serve to convince me without either the tradition or the history. It is a mere natural effect; and such, I apprehend, must be the economy of nature, in every case where the waters of a river are inclosed in any part of their course by elevated lands. The first consequence of this stoppage is, of course, the conversion of the inclosed lands into a lake: and if this happens near the fountains of the river, and the ground is solid, it is likely to remain a lake for ever; the river not having force enough in its infant state to work itself a passage through the mountains. Hence it is that more lakes are found near the sources of rivers, than in the lower parts of their course. If the river be inclosed after it has gained a great accession of water, and, of course, strength, it will indeed at first form a lake as before; but in time, the place at which it runs over will be gradually fretted away, as in the case of the Chelum above mentioned. The Euphrates, in like manner, opens itself a passage through Mount Taurus;

[a] Rennell's Hindostan, p. 104, 106.

and the Ganges through the Himmaleh mountains: and even though the base of the mountain be of the firmest texture it will give way to the incessant friction through a course of ages [b]. The Valley of Nepaul, separated from Tibet by a part of the Himmaleh mountains, is about four thousand feet above the level of the sea, and Colonel Kirkpatrick thinks, that all the arguments used by Major Rennell to shew that Cashmere was once a lake apply with equal force to the Valley of Nepaul [c].

It is Saussure's opinion that the Lake of Geneva occupies the place of some of the lower beds of the great amphitheatre of the Alps; and he grounds his opinion on the following facts. Almost all the strata forming the exterior ridge of the Alps descend gently towards the Alps, but have their escarpment towards the Lake [d]. The strata round the eastern extremity of the Lake of Geneva have their escarpments towards the Lake; their dip in the opposite direction [e]. The strata of Saleve, which chain is a continuation of Jura, descend very gradually towards the high Alps on the south-east, having an abrupt escarpment towards the valley of the Lake of Geneva [f]. The same observation applies to the Voirons, and also to the strata about Meillerie, opposite Lausanne, and the three exterior chains of the Alps, situated beyond the Saleve and the Voirons;

[b] Rennell's Hindostan, p. 107.
[c] Kirkpatrick's Nepaul, 171 and 114.
[d] Saussure, tom. i. p. 299.
[e] Ibid. tom. iv. p. 380.
[f] Ibid. tom. i. p. 245.

on the shores of the West India islands; but no reefs have been discovered there[m]. Captain Flinders however says, that the Gulph of Florida is formed by the coast of America on the west, and by a great mass of coral islands and shoals on the east: and he adds, that there is a resemblance therefore between the northern and southern hemisphere, with respect to the prevalence of coral reefs, at nearly an equal distance from the equator[n].

The tropical islands are divided by Forster into high and low. There are many of the former, which have mountains whose summits are scarcely ever free from clouds; some indeed whose summits are covered with perpetual snow, as in New Zealand[o]. The low tropical islands are commonly narrow low ledges of coral rock, including in the middle a large lagoon, or lake, and having here and there little sandy spots somewhat elevated above high water, on which cocoa-nuts thrive[p]: correspondent with which description is the account given by Captain Cook, on the occasion of discovering one of these coral reefs, which was at first mistaken by him for land. "This proved to be," he says, "another of those low or half drowned islands; or rather a large coral shoal of about twenty leagues in circuit. A very small part of it was land, which consisted of little islets ranged along the north side, and connected by sand-banks

[m] Barrow's Cochin China, p. 167.

[n] Flinders's Voyage, vol. ii. p. 103.

[o] Forster's Voyage, p. 31.

[p] Ibid. p. 15.

and breakers. These islets were clothed with wood, among which the cocoa-nut tree was only distinguishable. We ranged the south side of this shoal at the distance of one or two miles from the coral bank, against which the sea broke in a dreadful surf. In the middle of the shoal was a large lake, or inland sea, in which was a canoe under sail[q]." These coral reefs are so numerous in this part of the world, that M. de Bougainville gave them the name of the dangerous Archipelago: and as they intercept the swell of the sea, it is always a sign of their neighbourhood, when the sea is calm in these latitudes[r].

Captain Flinders says, the quantity of coral reefs between New Holland, and New Caledonia, and New Guinea, is such, that this might be called the Coralline Sea[s]. Thus, for 350 miles in a straight line from south-east to north-west on the east coast of New Holland, is a coral reef, or barrier, uninterrupted by any large opening into the sea: and this reef is probably connected with others, so as altogether to make an extent of nearly 1000 miles, having a mean breadth of from twenty to fifty miles[t].

I need not here describe the character of coral farther than to state, that it is a natural form of carbonate of lime, produced by an animal of the polype kind; in consequence probably of the union of the carbonic acid evolved from the surface

[q] Cook's Voyages, 1772, vol. i. p. 142.

[r] Ibid. p. 144.

[s] Flinders's Voyage, vol. i. p. 314.

[t] Ibid. tom. ii. p. 102.

of its own body with the lime, which is one of the constituents of the saline matter of the sea. The particles of carbonate of lime, however produced, are cemented together so firmly by a glutinous secretion of the same animal, as to acquire a degree of consistence, which not only forms a safe habitation for a race of animalcules, from their soft texture most obnoxious to external injuries, but which is calculated to resist the utmost action of the sea, and in many instances to protect the original surface of the earth itself from its assaults. Thus almost all the tropical islands which Cook saw in the South Pacific Ocean are guarded from the sea, to a greater or less extent, by a reef of coral rocks, extending out from the shore to the distance of six hundred feet and farther; and on this reef the force of the sea is spent before it reaches the land: and thus nature has effectually secured these islands from the encroachments of the sea, though many of them are mere points when compared with that vast ocean [s].

As the specific gravity of coral is greater than that of sea water, the structure of a coral reef necessarily commences either from the natural bed of the ocean, or from the surface of some submarine rock; and, as may be collected from the nature of the soundings among coral reefs, the whole structure is very frequently disposed in the form of a crescent, sometimes even approaching to a circle. This crescent is on the convex side built up throughout in very nearly a perpendicular direc-

[s] Cook's Voyages, 1772, vol. i. p. 212.

tion, so as to form a wall, which is exposed to that quarter from whence a stormy sea most frequently prevails. The interior of the structure seems gradually to shelve off, so that about the centre of the inclosed, or partially inclosed space, the sea is found of its natural depth.

Correspondently with such an arrangement, it happens usually that the soundings gradually lessen from the centre of the area inclosed by a coral reef towards the exterior ridge, and then suddenly sink to two hundred fathoms or more. Thus Captain Flinders says, that on the outside of the great barrier of coral off the east coast of New Holland the sea appears to be generally unfathomable; but within and among the reefs are soundings every where [x]. On another occasion he mentions a circular coral bank, about four miles in circumference, in which the soundings change at once from ten to nearly a hundred fathoms [y]. And Forster says, that coral islands have often very deep soundings immediately in their vicinity [z]. And Cook says, that coral shoals very frequently consist of a number of little islands, ranged in a circular form, and connected together by a reef or wall of coral rock [a], and sometimes by *sand-banks* [b]; and that on the outside of these shoals the sea is in general every where unfathomable. These islands are often inhabited, having been colonized

[x] Flinders's Voyage, vol. ii. p. 115.

[y] Ibid. vol. i. p. 250.

[z] Forster's Voyage, p. 55.

[a] Cook's Voyages, vol. i. p. 315.

[b] Ibid. vol. ii. p. 2.

from the *high* tropical islands; but the inhabitants are obliged to live principally upon fish [c].

To the foregoing account I shall subjoin the opinion of Captain Flinders on the process observed by nature in the formation of coral reefs. "It seems to me," he says, "that when the animalcules, which form the corals at the bottom of the ocean, cease to live, their structures adhere to each other by virtue either of the glutinous remains within, or of some property in salt water; and the interstices being gradually filled up with sand and broken pieces of coral washed by the sea, which also adhere, a mass of rock is at length formed. Future races of these animalcules erect their habitations upon the rising bank, and die in their turn, to increase, but principally to elevate, this monument of their wonderful labours. The care taken to work perpendicularly, in the early stages, would mark a surprising instinct in these diminutive creatures. Their wall of coral, for the most part built in situations where the winds are constant, being arrived at the surface, affords a shelter, to leeward of which their infant colonies may be safely sent forth; and to this their instinctive foresight it seems to be owing, that the windward side of a coral reef, exposed to the open sea, is generally, if not always, the highest part, rising almost perpendicularly sometimes from the depth of two hundred and perhaps many more fathoms.

"To be constantly covered with water seems

[c] Cook's Voyages, vol. i. p. 315.

necessary to the existence of the animalcules, for they do not work, except in holes upon the reef, beyond low water mark: but the coral sand, and other broken remnants thrown up by the sea, adhere to the rock, and form a solid mass with it, as high as the common tides reach. That elevation surpassed, the future remnants, being scarcely covered, lose their adhesive property, and, remaining in a loose state, form what is usually called a *key* upon the top of the reef. The new bank is not long in being visited by sea birds; salt plants take root upon it, and a soil begins to be formed; a cocoa-nut or the drupe of a pandanus is thrown on shore; land birds visit it, and deposit the seeds of shrubs and trees; every high tide, and still more every gale, adds something to the bank; the form of an island is gradually assumed, and, last of all, comes man to take possession [d]." In the base of a coral island of the above description, Captain Flinders distinguished not only the sand, coral, and shells, formerly thrown up, in a more or less perfect state of cohesion; but also small pieces of wood, pumice-stone, and other extraneous bodies, which chance had mixed with the calcareous substances when the cohesion began, and which in some cases were still separable from the rock without much force [e].

It appears then, that, in some instances, sand, and shells, and other extraneous substances, brought by the sea perhaps from some distance,

[d] Flinders's Voyage, vol. ii. p. 115 and 116.

[e] Ibid. p. 116.

are washed up upon coral banks; and it is stated by Captain Flinders, that such sand-banks are found in different stages of progress; some being overflowed with every returning tide; some raised above high water mark, but destitute of vegetation; some, lastly, habitable and abounding in trees [f]. Correspondent with what has been just said is another observation of Captain Flinders, that coarse coral sand, composed of sand and broken shells and coral, often occurs, as soundings, off the coast of New Holland [g]. On the upper surface of coralline islands are often also found, imbedded in the coralline mass, individuals of a gigantic species of the shell called the chama. This is the case, according to Barrow, in the coralline islands near Batavia [h]; and Captain Flinders observed the same thing off the east coast of New Holland [i].

To the foregoing account I subjoin the two following notices, respecting the existence of submarine banks of shells, as being evidently connected with the present subject. It is stated by Lamarc, that submarine banks are known to exist, of thirty leagues in extent, consisting of the debris of animals; many of which are shells of the most delicate texture, and in a complete state of preservation [k]. And in Investigation Straits, 35 south lat. 137 east long. Captain Flinders met with banks or

[f] Flinders's Voyage, vol. ii. p. 115.
[g] Ibid. vol. i. p. 178.
[h] Barrow's Cochin China, p. 165.
[i] Flinders's Voyage, vol. ii. p. 88.
[k] Ann. du Mus. tom. i. p. 300.

ridges of microscopic shells, of various kinds, not larger than grains of wheat. These ridges reached high water mark [l].

In reviewing the subject of the present chapter, I am ready to allow, that the description of the islands above mentioned, consisting of sand and coral and broken shells, appears closely applicable to some parts of that limestone stratum, which belongs to the Oolite formation, and is commonly known by the name of Coral Rag. Moreover, the recent coralline beds of Batavia and Vera Cruz, being actually employed, according to Barrow and Humboldt [m], in the buildings and fortifications of those places, shew a degree of firmness in the recent substance, which renders it equally applicable to the purposes of masonry with the fossile stratum. A slight consideration of the subject, however, will serve to shew, that fossile coralline strata must have been formed by a very different process from that which is now going on. In the first place, no instance has yet, I believe, occurred of coralline strata two hundred fathoms in thickness, nor any instance of that peculiar arrangement in the fossile coralline strata which characterizes the recent reefs: and if it should be said, in answer to this, that the original reefs were probably broken up, and that the stratum called the coral rag, for instance, which approaches the nearest in character to a coral bank, has been

[l] Flinders's Voyage, vol. i. p. 178.

[m] Barrow's Cochin China, p. 173; and Humboldt, tom. ii. p. 353.

formed from their debris; it may then be asked, why do not the fragments of the fossile stratum appear to be water worn? which, to the best of my recollection, is not the case in any instance; and for the most part, indeed, the coralline remains are delicately preserved. Or, if this objection were satisfactorily answered, in what manner can we account for the singular fact, that, within the limits of a small space, the fossile corallines sometimes resemble in texture the general character of the stratum in which they occur, sometimes are completely in the state of compact spar? Or, again, why are these fossile coralline remains accumulated in particular beds, and not found also in those which are intermediate?

There is a reflection in Brongniart's Essay on the Mineralogy of the Basin of Paris, which is applicable to the present subject. In speaking of the shells of some of the Paris beds, he says, "Certainly, in that ancient ocean, in which these fossile shells were deposited, circumstances were very different from those of our present ocean. We have no experience of the formation of submarine strata; and the shells which occur in our seas are always the same in the same parts of the coast. It has not been observed, for instance, during the period in which oysters have been fished for near St. Malo, that those shell-fish have disappeared and been succeeded by others of a different genus[n]." As far as it can be ascertained, it appears that in particu-

[n] Ann. du Mus. tom. xi. p. 312.

lar places the depth of the sea remains now what it was two thousand years since; and the same shells, which were fished for then, are found now.

The following extract from Mr. Salt's Abyssinia, though connected with the foregoing account of coral reefs, has been withheld hitherto; because it seems questionable whether the islands here spoken of can be considered as recent coral beds. Mr. Salt says, that in the Bay of Amphila (which is on the western shore of the Red Sea, and about two degrees and a half from the Straits of Babelmandeb) are thirteen islands, all of which (excepting one, which is a solid rock of calcareous stone, containing veins of calcedony) are composed entirely of marine *alluvies*, as fragments of coral &c. strongly cemented together, and forming vast and solid masses, which may not improperly be termed rock; the surface being covered in parts only with a thin layer of soil. The low grounds of all the islands about thirty or forty miles to the north of Amphila Bay are of the same coralline character. The larger portion of these remains consists of corallines, madrepores, echini, and a great variety of sea-shells of those species which appear to be still common in this sea. The height of the islands often exceeds *thirty* feet above the level of high water mark; a circumstance which renders it difficult to account for the process by which they have been formed: for Mr. Dalrymple's hypothesis, which accounts for coral islands that are

not elevated more than *one* or *two* feet above the level of the ocean, does not solve the present difficulty; since on the islands above described large pieces of madrepore are found disposed in regular layers full *twenty* feet above the level of high water mark: for which circumstance, Mr. Salt says, no satisfactory reason can be assigned in his opinion, but the supposition of the sea having retired since they have been so deposited [q].

As it is known that the increase of recent coral ceases as soon as it has reached the surface of the water; and as the action of high tides and winds cannot accumulate sand &c. upon coral islands to above the height of one or two feet, (on which circumstances I believe Mr. Dalrymple's hypothesis rests,) it seems probable that the islands of Amphila Bay, described by Mr. Salt, may be fossile strata. But of course I speak with much hesitation on this point, and not without apologizing for the liberty.

CHAP. XXIV.

On inland Accumulations of Sand.

THE existence of those deserts or barren plains of sand so common in Africa and Asia is a fact familiar to all: few however are perhaps aware of their aggregate extent. The great sandy desert of Persia

[q] Salt's Abyssinia, p. 189 and 168, 169.

alone, which is situated principally in Mekran, (the ancient Gedrosia,) occupies a space of nearly a hundred thousand square miles [r]. And it is stated by Lacépède, that the great Sahara of Africa, measuring one thousand leagues in length, (from Cape Blanc to the Nile,) and four hundred leagues in breadth; the desert of Arabia, with a considerable part of Arabia Petræa; the interior of Persia; the plains of Tartary; and various other similar sandy tracts, equal nearly one third of the surface of the old continent [s].

These deserts are barren plains taken generally, but are sometimes interspersed with fertile spots, as in the Oases of Africa: and with respect to many of the deserts of Tartary, known by the name of *Steppes*, they not only contain numerous pastures, but almost throughout abound with springs. The sand indeed, of which they are composed, seems to be saturated with moisture; for Pallas, in speaking of the sandy desert or steppe of Naryn, says, that wherever the sand is dug into, water is soon found, and that the Calmucs keep trenches open in various parts as reservoirs; and that, if you find any of these trenches dried up, you have only to tear up by the roots the rushes that grow in them, and clear away the slime that occupies the surface of the sides and bottoms, and then the water immediately begins to ooze into the trench [t]. The Dean of Westminster mentions a similar circumstance on the coast of Persia. Several voyagers

[r] Kenneir, p. 122.
[s] Ann. du Mus. tom. vi. p. 286.
[t] Pallas, tom. v. p. 130.

acquaint us, he says, that wherever palm trees grow, however arid the soil, there is always water to be found by opening the ground to the depth of from ten to fifteen feet [s].

The following is a description of the great steppe called Naryn by the Calmucs. It commences about the 49th degree of north latitude; extending from thence in a southerly direction as far as the Caspian Sea, and occupying a considerable proportion of the country between the Volga on the west and the Oural on the east: towards the southern extremity is a continuity of barren plains, and of rich pastures which meander among hills of moving sand. Notwithstanding this predominance of sand, there occur occasionally vallies, or rather depressions of the surface, of a remarkable verdure, and luxuriant in reeds and shrubs and thickets; and in every part, and in the driest season, you find water, in digging but a little beneath the surface, even in the hills of moving sand: so that, if you make an excavation, particularly where any verdure is visible, the excavated part soon becomes filled with water, which not only issues from the bed of the excavation, but from even the upper part of its sides [t].

The Calmucs suppose the Caspian Sea once occupied all this part of the steppe of Naryn; and thus account for the numberless sources, not only of fresh but salt water, which occur in it: and Pallas says their supposition is natural; for both

[s] Voyage of Nearchus, p. 210. [t] Pallas, tom. v. p. 128.

the sand and the argillaceous soil subjacent to it are fully charged with pectinites and other marine shells: and these shells resemble those of the Caspian, but not of the Oural or Volga; and the soil is besides every where a sand united by sea-silth [u]. But even the lowest sand hills of this desert are much elevated above the level of the Caspian; which therefore cannot be the feeder of those springs: nor can the salt lakes in the northern part of the steppe be the feeders, for they are most of them below the level of this part of it. Pallas himself thinks these springs arise from a communication with more northern steppes, which occupy a much higher level; and also from the mountains which border on and intersect the steppe: for these mountains, though not very high, have numerous springs thrown out by horizontal beds of clay [x].

Pallas supposes with Tournefort, that originally the Euxine, Caspian, and Aral were one sea, and that the Euxine was then not united with the Mediterranean; but that that sea forcing a passage through the Hellespont, the Caspian by the sudden drain became separated from the Euxine and the Lake Aral; and the steppes, with their numerous saline lakes, which surround the Caspian and the Aral, were exposed to view [y]. And he thinks that the sand of the Tartar steppes has in some instances been derived from the disintegration of neighbouring strata. Thus in the

[u] Pallas, tom. v. p. 188.

[x] Ibid. p. 131.

[y] Ibid. p. 228.

south-east parts of Siberia are extensive and very elevated plains, the surface of which is covered with sand, which has evidently been derived from the mountains of that neighbourhood, (which are conglomerates;) the sand having been amassed partly by winds, partly by rivers [z]. Again, in speaking of a sandy tract of land adjacent to the Lake Baikal, he says it has been gradually formed by the disintegration of adjoining granitic mountains, which are easily acted on by the weather [a].

In every part of the world where the surface is sandy, the sand is frequently driven about by the wind, in consequence of which it drifts into those hillocks or heaps called *dunes*. Such dunes, or accumulations of sand, are not uncommon in this island, as in some parts of Suffolk, which are exposed to the action of west-south-west winds, blowing across the great level of the plains of Cambridgeshire. Humboldt says, that the neighbourhood of Vera Cruz is a sandy plain, in which dunes are elevated by the north winds, that blow from October to April, to the height of from twenty-four to thirty-six feet; and that these hills of moving sand, which every year change their form and situation, are frequently separated from each other by stagnant marshes. He adds, that the sand thus accumulated covers the native rock to so great a depth, that no stone is met with in the neighbourhood [b].

Mr. Salt says, that, in the part of Africa near the

[z] Pallas, tom. iv. p. 387.
[a] Ibid. p. 419.
[b] Humboldt, tom. ii. p. 353.

Straits of Babelmandeb, the north-west wind loads the air with sand, which the force of partial gusts of wind carries up in the shape of pillars, which were constantly observed sweeping in different directions across the plain[c]. With whatever obstacles this drifted sand meets, it of course overwhelms them; and it is observed by Denon, that small eminences of sand in Lower Egypt almost invariably contain antiquities; for these eminences appear to have been formed by the drifting and accumulation of the sand round the remains contained within them[d]. It is said by the same author, that, though a chain of hills, which separates Lybia from Egypt, forms a barrier to the banks of the Nile against the sands of the desert, yet the inundation of sand often overwhelms parts of the country, leaving no other marks of vegetable life than the tops of a few palm trees, together with the roofs of buildings, which only add to the dreary aspect of destruction[e]. Nothing is so melancholy to the feelings, he says, as to march over the thus ruined villages, to tread under foot the roofs of houses and the tops of minarets; all which is the effect of the encroachment of the sand[f]. The province of Seistan in Persia, from the south part of which the rivers between Ormus and the Indus take their rise, is flat and sandy, and thinly inhabited. In this district a wind blows for one hundred and twenty days, during the hot months, with such violence as to overwhelm, with clouds of

[e] Salt's Abyssinia, p. 180.
[c] Denon, vol. i. p. 162.
[d] Denon, vol. i. p. 125.
[f] Ibid. p. 209.

sand, houses and gardens and fields [g]. Between the mouths of the Oural and the Volga, plains of moving sand are very common, driven by the wind, and sometimes overwhelming houses [h]. Horneman observed that the progress of the moving sands in Lybia is very generally eastward; and that, in their line of march, every obstruction gives rise to a sand-hill: but (as is stated from his notes) he more particularly remarked a smaller kind of sand-hill formed by the obstruction of the trunks of palm trees, and so high as to leave to the view nothing more than the topmost branches [i].

In some situations the drifting of sand is prevented by natural barriers of mountains; and such favoured spots, if they also abound in springs, appear as verdant islands in the midst of the scorching ocean which surrounds them. Such is the Oasis of Ammon, which still remains uninjured after the lapse of ages.

There is a circumstance very well worth mentioning with respect to the form which drifted accumulations of sand are disposed to assume. Saussure, in describing part of the coast of Genoa, speaks of heaps or hillocks of sand, driven up by the sea wind, which are abrupt, or have an escarpment looking *inland*, but slope gently toward the *sea*: and he adds, that he has made a similar observation with respect to the sand brought down by rivers; which is usually accumulated in inclined planes, the escarpment of which looks to-

[g] Kinneir, p. 189.

[h] Pallas, tom. v. p. 150, 163.

[i] Horneman's Journal, p. 142.

wards the valley, and not towards the mountains from whence the sand has been brought [k]. In a similar manner, the sand of the great desert of Persia is raised by the wind into longitudinal waves, which present, on the side towards the point whence the wind blows, a gradual slope from the base: but on the other side they rise perpendicularly to the height of ten or twenty feet; and, being of a red colour, they have at a distance the appearance of a new brick wall [l]. Most of my readers have probably observed an appearance similar to that above described in the case of drifted snow.

CHAP. XXV.

On the earthy Deposition of Carbonate of Lime, called calcareous Tufa.

IT is very generally known, that almost all the natural springs of a district, in which carbonate of lime or common limestone abounds, to a certain extent dissolve and retain in solution particles of the calcareous strata among which they have been formed; and that, upon exposure to the open air, they deposit these particles, in the form of an incrustation, on whatever substances are presented to them.

I formerly supposed, with many others, that the

[k] Saussure, tom. v. p. 293.

[l] Kinneir, p. 224.

solvent power of the water thus exerted on the particles of the limestone depended on the presence of uncombined carbonic acid; and that this uncombined acid evaporating from the surface of the water, after exposure to the external air, the calcareous carbonate was necessarily deposited. Circumstances, however, having led me to make repeated and particular observations on the fact, I have found, that the solvent power of simple water in such instances is much greater and more rapid in its action than I once supposed. I do not of course mean to deny, that in many natural springs, holding carbonate of lime in solution, uncombined carbonic acid may be present; and I allow of course also, that in such cases the solvent power of the water would be increased.

Of the ready solubility of carbonate of lime in water, any one may convince himself by the following simple experiment: If half an ounce of distilled water be agitated for a short time in contact with a few grains of pulverized carbonate of lime, it will be found, that, upon the addition of a proper test, (oxalate of ammonia for instance,) the water will be rendered turbid. It appears to me then, that when a spring, charged with as much calcareous matter as it is capable of holding in solution, has issued from beneath the surface of the earth, and the requisite quantity of the solvent has been diminished by evaporation, the liberated particles of the calcareous matter are consequently precipitated. But if the solution of the earthy matter is to be accounted for solely by the presence of disengaged carbonic acid, then almost all springs in a limestone district

ought readily to form calcareous depositions; which certainly is not the case: whereas, if it be supposed that many springs are not nearly saturated with the earthy matter, it is clear that a deposition will not, within certain limits at least, be the necessary consequence of evaporation.

Correspondently with what has been above said, such springs as hold little if any calcareous carbonate in solution will have the quality of removing, instead of depositing, earthy matter: and it has been stated, as a proof of the purity of the water of the spring at Malvern, that if used for culinary purposes, it gradually removes the earthy incrustation deposited on the inner surface of vessels which have been previously employed in boiling the water of less pure springs: and such incrustations are well known to consist almost entirely of carbonate of lime. Although the foregoing observations and consequent conclusions have probably been made by others as well as myself, yet, as I believe they are not very commonly known, (for Cuvier, in his latest geological publication, attributes the solution of calcareous carbonate to the presence of a superabundant portion of carbonic acid in the springs containing it[m],) I have thought it worth while to detail them.

The two following instances of a crystallized deposition of carbonate of lime, from an aqueous solution, are sufficiently connected with the present subject to justify their insertion in this place. On

[m] Cuvier's Essay on the Theory of the Earth, p. 33.

two occasions I have accidentally met with transparent and regularly defined crystals of carbonate of lime, which must have been formed on the spot where I found them within the space of the preceding six months. In one of these instances the crystals were formed in a bottle of lime-water, containing a quantity of undissolved lime mixed with carbonate of lime; the latter of which had been gradually formed by admission of air in consequence of repeated removal of the cork. Several minute crystals of this carbonate of lime were found adhering to the side of the bottle; and one of these was a compound crystal, consisting of a considerable portion of a smaller hexagonal plate projecting from a larger: the diameter of the larger, as far as I recollect, (for I sent the specimen to Dr. Wollaston,) was at least the twelfth of an inch; but the form even of the smaller was easily ascertained by the naked eye. The crystals were not transparent in every part, but had that partial opacity so common in calcareous crystals. In the other instance a number of polyhedral and perfectly transparent crystals, but too minute for the naked eye to distinguish their form accurately, were found adhering to the sides of a large tub, which had been filled with the common spring water of Oxford six or eight months previously; and in which the same water had constantly remained, subject only to slight and occasional disturbance.

I am aware that the foregoing are not entirely new facts, since crystals of carbonate of lime stalagmitically formed are by no means of rare occur-

rence in natural calcareous caverns. They may however be considered as unexpected illustrations of the natural process.

In general the calcareous matter, deposited from springs &c. occurs in the form of a porous spongy mass, called by mineralogists calcareous tufa; which in many places is deposited in such abundance as to be extensively employed in building: but as the process of its formation is very simple, and the fact very generally known, I do not think it necessary to dwell long on the subject, and shall therefore close this account with the few following notices of its occurrence.

Saussure says, that beds of tufa are very common among the mountains which terminate the high vallies of the Alps[n]; and De Luc speaks of promontories of tufa in some of the vallies of Switzerland; adding, that the canals which are cut in the substance of this tufa, for the purpose of conveying water, are soon choked up by the deposition of fresh earthy matter[o]. The Wiesent near Bayreuth deposits tufa in great abundance, as also do many of the brooks which run into that river; and this tufa is used as a building stone.

It is stated in the Philosophical Transactions for 1774[p], that before Matlock was frequented on account of its waters, and when those waters had not been confined for the purpose of the bath &c. they had formed a stratum, as it were, in their course, from the hill lying to the west, and situated

[n] Saussure, tom. iv. p. 14.

[o] De Luc's Travels, vol. iv. p. 42.

[p] Philosophical Transactions, 1774, p. 124.

behind the present bath, into the Derwent. The dimensions of this stratum were five hundred yards in length, often one hundred yards in breadth, and from three to four yards in depth. It contained moss, snails, trunks of trees, &c. and any thing that obstructed the passage of the water from which it was deposited. It is added, that in the neighbourhood of Matlock whole houses are built of this stone, which, like many common limestones, hardens by exposure.

CHAP. XXVI.

On Volcanoes and Earthquakes.

THE extensive agency of subterraneous fire is abundantly made evident by the existence of volcanoes in every part of the world: and it seems impossible to reject the testimony which has been brought forward in favour of the opinion that regular strata have been deposited in some instances on extinct volcanoes. De Luc, among many others, has observed strata of secondary limestone superincumbent on extinct volcanoes; which shews, he says, that a deposition had taken place from the sea after the volcanic action had ceased.

The Andes, which extend 5000 miles in length, abound with volcanoes; and Chimboraço, the highest mountain of the world, is probably an extinct volcano; for its ascent is covered with pumice stones and vitrified masses, and altogether resembles the currents of lava of that district.

With the exception of the Peak of Teneriffe and a few other instances, the volcanoes of the old world do not occur at a very high degree of elevation; but the volcanoes of the Cordilleras of New Spain themselves rise, like colossal summits, on the ridge of those lofty mountains, forming, as it were, their crest. Of these volcanic summits there are two near the valley of Mexico, remarkable as forming the pass by which Cortez advanced with his army[v]; of which one is as high, the other is two thousand feet higher than Mont Blanc[r]. These two summits, though usually distinct and insulated, are sometimes nearly united by continued glaciers[s]: and the higher of the two, situated in the midst of perpetual snow, forms an enormous cone, the crater of which is in a constant state of activity; casting out smoke and cinders, but no flame[t].

At present there are in New Spain only five volcanoes in a state of activity[u]; though many, which are now extinct, appear to have existed formerly to the north, and in Old California[x]: but it appears, that between the parallels of eighteen and twenty-two, there is an active subterranean fire, which from time to time breaks through the crust of the globe, in a direction from east to west, even at a great distance from the coast[y]. Humboldt says, that of the five burning volcanoes of New Spain, that which is called Jorullo made its ap-

[r] Humboldt, tom. i. p. 169, 174.
[s] Ibid. p. 173.
[t] Ibid. tom. ii. p. 140 & 267.
[u] Ibid. tom. i. p. 303.
[x] Ibid. tom. ii. p. 423.
[y] Ibid. tom. i. p. 304.

pearance in the year 1759. It broke out in the province of Valladolid, on the western declivity of the Cordilleras, at the distance of thirty-six leagues from the coast, and at more than forty-two leagues from any volcano now in activity; and suddenly formed a mountain of scoriæ and cinders, rising about 1600 feet in height above the level of the surrounding plain, in the midst of many hundred other small inflamed cones[a]. In another part of the same province, and in the same year, a tract of three or four miles square was raised up above the level of the surrounding ground; the limits of which catastrophe may be seen at the present day by the fractured state of the strata. The heat of the crevices in these fractured strata is even now near that of boiling water: and subterraneous murmurings are heard on the spot; which it is probable proceed from water in a state of ebullition, for there was an ejection of muddy matter at the original eruption of the volcano in 1759[b]. These subterraneous murmurings of volcanoes are sometimes heard like the noise of artillery at the distance of sixty or seventy leagues[c]. It may be remembered, that the late eruption in St. Vincent's was said to have been preceded by explosions as of artillery.

There is a paper in the Philosophical Transactions for 1708, giving an account of a new volcanic island which was formed in the preceding year in the bay of the island of Sant-Erini, the Thera of

[a] Humboldt, tom. ii. p. 290 &c.
[b] Ibid. p. 294, 295.
[c] Ibid. tom. ii. p. 345

the ancients; which is situated in the Mediterranean Sea, about twenty-eight leagues to the north of Crete. An earthquake had been very extensively felt in Sant-Erini two days previously to the appearance of the volcanic island; but no earthquake took place after its first appearance: and the island continued to increase very sensibly both in breadth and height, without any other accompanying alarming circumstance, till July 16th. At that time, after a continued agitation of the sea for some days preceding, with the casting up of many minerals, particularly sulphur, a chain of black rocks rose up, and soon joined themselves to the new island. On the 19th of July flames burst out from the newly formed island, preceded by submarine murmurings: these phenomena continued, with occasional showers of fine dust, (similar circumstances to which took place in the late eruption of St. Vincent's,) till the end of August; and, having then subsided for a time, were renewed with increased violence during September and the two following months: at which time the circumference of the volcanic island appeared to be about three miles: its height from thirty to forty feet[d]. The volcanic island continued to increase till May 1708; at which time it was nearly of the following dimensions.

In height, 200 feet.
In circumference, 5 miles.
In breadth, where broadest, 1 mile[e].

[d] Philosoph. Transact. 1708, p. 200, 208.
[e] Ibid. 1710, p. 372, 374.

On the north side of Sant-Erini there was formed a similar volcanic island in 726; the same island was increased in 1427 by another submarine eruption; and again in 1650[f].

I might here describe the formation of Monte Nuovo, a volcanic mountain three miles in circumference at its base, which was thrown up in the course of forty-eight hours in the year 1538, in the midst of a plain situated not very far to the north-west of Naples: but referring the reader to Sir William Hamilton's account of that mountain, in the Philosophical Transactions for 1771, I shall collect from the same most interesting paper some other circumstances tending to give a more general idea of the agency of volcanic fire.

In all points of view the neighbourhood of Naples is best calculated to give an impressive view of the character of a volcanic district: for no where, in the old world at least, have the phenomena of volcanoes been more frequent, or their effects more awful; and no where have such phenomena and their effects been more accurately observed and recorded. The names of Herculaneum and Pompeii are familiar to every one; and many are acquainted also with the fact, that both these places were buried by an eruption of Vesuvius about the latter end of the first century. Pompeii is distant from Vesuvius five miles in a straight line in a south-easterly direction. Herculaneum, over the site of which Portici is now situated, is just at the foot of Vesuvius in a direc-

[f] Philosophical Transactions, 1708. p. 67.

tion nearly west. As they were both buried about the same time, and both by eruptions of Vesuvius, it is clear that the surface of all the ground between them must have been volcanically formed since the commencement of that eruption: and it has been found that Pompeii is now from ten to twelve feet below the actual surface; and that Herculaneum is not less than from seventy to an hundred and twelve feet beneath the surface: but the *pavement* of Pompeii was found to be of lava, and *under* the foundation of the town is a deep stratum of lava; so that probably much of this part of Italy is of volcanic origin: and "Castel a Mare" (near which stood the ancient Stabiæ, which was buried by the eruption that destroyed Pliny) is still more distant from Vesuvius than Pompeii itself. Sir William Hamilton says that some of the cinders covering Pompeii are eight pounds in weight; yet these must have been projected from Vesuvius, together with the lighter ashes, in the form of a shower.

It is very probable that the surface of the whole interval between this part of the coast of Italy and the Apeninnes is volcanic. Thus the tract of ground called the "Campagna felice," occupying a large portion of this space, consists of four or five feet of excellent soil, under which are strata of burnt and erupted matter: and in advancing towards the sea you have the volcanic elevation called Solfaterra still retaining its conical form, and penetrated by several crevices, through which muriate of ammonia is sublimed by the subterranean heat; and from the sand of the plain beneath they

extract sulphur and alum; all of which substances are decidedly volcanic products: and "Forum Vulcani," the ancient name of Solfaterra, shows how long this place has retained its heat. To the south-east of Solfaterra is Monte Nuovo and the Lake Agnano, near which is a spring of water issuing at the boiling point; and near this is the Grotto del Cane; and to the north-west is the Lake "Avernus," which is even yet but rarely ferquented by birds: all which circumstances, joined with many other, and with the general aspect of this tract of country, sufficiently shew the nature of its origin[g].

If from this southern part of Europe we turn to Iceland, we there find equally evident proofs of both present and extinct subterranean fire: but there are few parts of the world where volcanoes are not found in a state of activity: thus exclusively of Etna, and Vesuvius, and Hecla, may be enumerated the volcanoes of the Indian Archipelago, of the Pacific Ocean, of the north-eastern parts of Asia, the West Indies, the Canaries, and the Azores, &c. &c.; besides numerous districts which appear to have been ravaged at some time or other by volcanic fire. But when, together with the multiplied instances of existing volcanoes, we contemplate the probability of their mutual connection, the consideration of the subject becomes truly awful. This connection is rendered sensible by some remarkable coincidences in time between the eruption of a volcano,

[g] Philosophical Transactions, 1771, p. 1—50.

and the sensation of an earthquake, or the cessation of that sensation: and the history of earthquakes themselves affords further instances of a probable connection between them and subterranean fire.

Earthquakes, which have occasionally been felt through the whole extent of the Altaïsch mountains, are not uncommon in the neighbourhood of the Lake Baikal: and it may be mentioned, in support of the opinion of the probable connection between volcanoes and earthquakes, that the mountains adjoining this lake have many warm springs; and that the lake itself throws up much bitumen [h]. And in support of the opinion that earthquakes have a very extensive range of action, it may be mentioned, that Captain Davis in the year 1687, being four hundred and fifty leagues from the main of America, felt an earthquake very strongly, when at the same time its most violent effects were observed at Lima and Callao [i].

The following facts shew in a very striking manner the connection between earthquakes and volcanoes.

Pallas says, that on the fifth of September 1790, a subterraneous rumbling, with violent thunder, was heard in the Sea of Asoph, about three hundred yards from the shore: then, with an explosion like that of cannon, an island, about the size of a large ancient tumulus, rose from out of the sea, which in that part was from twenty-five to

[h] Pallas, tom. iii. p. 342 and tom. iv. p. 396.

[i] Forster's Voyage, p. 156.

thirty feet deep. The island, which was about six hundred feet in circumference, appeared to raise itself, to break into chasms, and to throw out mud and stones, till smoke and *flame* at length broke forth: the perpendicular height of this island was about twelve feet. There was an amazing swell of the sea during the whole process, which lasted two hours: and in the course of the day two *earthquakes* were felt at the distance of fifty leagues. The final dimensions of the island were four hundred and thirty feet in length, two hundred and eighty-eight in breadth, and seven in height: but the following year the island disappeared [h]. In the same volume Pallas mentions an inland volcanic eruption of mud, in the eastern part of the Crimea; and he adds, there is a probability that in both cases coal beds were the occasion of the volcano [i].

In 1783, about the end of January, flames broke out from the sea thirty miles off Cape Reikianes at the south-west extremity of Iceland; and continued to burst forth during several months. In June earthquakes shook the whole of Iceland; the flames from the sea disappeared; and a dreadful volcanic eruption occurred at the Skaptaa Jokul, which is nearly two hundred miles from the point where the eruption took place in the sea [k]. A somewhat similar occurrence, though unaccompanied with any of the tremendous phenomena above described, is reported to have taken

[h] Pallas, Voyages, 1793, 1794. tom. ii. p. 273.

[i] Ibid. p. 274.

[k] Sir G. Mackenzie, p. 370.

place in 1755 at Luton in Bedfordshire. A pond in that town, in which there had been but little water for some weeks, suddenly filled, and a copious sediment was thrown up from the bottom, at the precise time of the earthquake at Lisbon. The above account is taken from the second Report of the State of the Bogs in Ireland; where it is added, that a similar circumstance occurred in the same pond in September 1809 or 1810[l].

Barrow in his account of Cochin China says, that in 1757, eighteen small islands appeared above the surface of the sea near the Azores, at the termination of a tremendous earthquake, which had continued eight days: they gradually however subsided, and at last disappeared; that part of the sea in which they had arisen being very materially decreased in the depth of water[m].

Very numerous facts of a similar nature to those recorded in this chapter might be, no doubt, collected; but enough has been said to justify the conclusion of Mr. Playfair; who says, that the cause of earthquakes is certainly a force that resides very deep under the surface: otherwise the extent of the concussion could not be such as has been observed in many instances[n].

It is the opinion of Werner, and therefore entitled to attention, that volcanoes arise from the burning of a quantity of coal locally accumulated, among rocks capable of producing lava[o]: but it

[l] Second Report of the Irish Bogs, p. 176.

[m] Barrow's Cochin China, p. 153.

[n] Playfair Illustrations, p. 91.

[o] Jameson, vol. iii. p. 219: and Comparative View, p. 59.

seems to be an obvious question, and not easily answered, how volcanoes when once extinct are again renewed in the same place; a circumstance which happens repeatedly. It is a more rational inquiry to investigate the degree of heat present in those natural furnaces, and the character of the lava and other substances which they eject. It has been stated, with respect to the first point, that the heat of volcanoes does not probably exceed 120 of Wedgwood's pyrometer, (which is scarcely so much as the full heat of a smith's forge,) for various minerals fusible at 100 or 110, are found unaltered in lava[o]. Ferrara seems to think that the continued fluidity of lava (and it often remains fluid for a great length of time) is owing to the sulphur contained in it: which sulphur has been derived from the pyrites of the rocks in which the volcanoes were formed. He says, that in general the substances acted on by the volcanic heat are so little altered, that they are very easily recognized: the crystallized substances, for instance, which they contain, even those which are most fusible, remain unaltered. Thus he possesses blocks of porphyritic lava, which can scarcely be distinguished from the natural rock: so that these lavas, though they have been melted, have not been also vitrified[p].

There seems to be some ground for assenting to the proposition, that the seat of volcanoes is very frequently in rocks, of which hornblende forms a constituent part: but then rocks of this kind are

[o] Comparative View, p. 58.

[p] Ferrara, p. 177, 179.

so very predominant at the surface, that we may well expect to find them also at considerable depths beneath the surface of the earth. Dolomieu however observes, that as it is essential to the volcanic production called pumice to contain no iron, it cannot be referred to hornblende rocks, as other lavas are: and as it sometimes contains particles of mica, and even small fragments of granite, he thinks it may be derived from rocks of that class: and he adds, that many granites are capable of imperfect fusion, making a *frit* of a white colour, in consequence of their containing no iron [q]. Again, some volcanoes have never been known to produce any running lava. Thus Humboldt says, that the volcanoes of the province of Quito, the most elevated plain of the whole world, which burst forth in 1797 with great violence, send forth flames to the height of 3000 feet, but have never produced a particle of true lava: they eject only water, sulphuretted inflammable air, mud, and carbonated clay [r].

The fertility of some volcanic districts is proverbial. Dolomieu says, that nothing can be more luxuriant than the fields of Catana; and Ferrara in his general account of Etna says, that its volcanic productions are admirably calculated to promote vegetation, and hence the fertility of the sides of that mountain [s]. It is supposed that in the progress of that alteration, which converts lava into vegetable soil, the iron of the lava first becomes

[q] Iles de Lipari, p. 61, 66.

[r] Ann. du Mus. tom. ii. p. 174.

[s] Ferrara, p. 319.

oxydated, and the argillaceous part imbibes moisture; whence each occupying a greater space than it did before, the whole mass swells and falls to powder: but there is no fixed law respecting the time when the commencement of vegetation takes place upon recent lava; accidents, of the weather, of the composition of the lava itself, &c. determining this point. Lichens, moss, and small plants first grow, and afford a soil for larger vegetables[t]. The lava of the eruption of the 96th Olympiad, about 400 years before the birth of our Saviour, scarcely supported vegetation till the end of the 17th century. The lava of 1408 already bears vines and other trees: and that of 1636 also bears vines and fruit trees: while the lava of 1381 and 1536 are still almost barren[u].

Lavas often resemble natural rocks, to which when they approach very nearly in external characters, the knowledge of the following marks of distinction may be of service. According to Mr. Playfair, lavas, known to be such, never contain calcareous spar or zeolite[x]: and according to Mr. Jameson, they also never contain water of composition[y]. Both these circumstances are accounted for by the slight degree of pressure that has acted upon them while in a state of fusion. I may here add that lightning, by superficially vitrifying the exposed parts of a rock, will sometimes lead an inexperienced geologist into an error respecting its origin. Saussure met with instances of this

[t] Ferrara, p. 346.
[u] Ibid. p. 350.
[x] Playfair's Illustrations, p. 68.
[y] Jameson, vol. iii. p. 196.

kind in the Alps [a]. With the exception of which however, and of the occasional appearance of warm springs, he says, in another part of his works, that he did not perceive the slightest trace of subterranean fire in those mountains [b].

It has been stated above, as the opinion of Werner, that volcanoes arise from the burning of a quantity of coal locally accumulated in the interior of the earth. This opinion derives some support from the analogy of the combustion of seams of coal near the surface of the earth, and the resemblance of the products of that combustion to true volcanic products; and hence has arisen the term "pseudo-volcano." Daubuisson has seen instances in the Meisner and other mountains in the neighbourhood of Hesse Cassel, where a few seams of coal catching fire, and continuing to burn to some extent beneath the surface of the earth, have given rise to the production of heaps of scoriæ and vitrified masses of earth; whence are obtained those "porcelain jaspers &c." so common in cabinets; and which are nothing more than indurated or semivitrified clays [c].

Mr. Farey says, that in some of the Derbyshire coal strata, a thin seam is found near the top of the coal, of greyish earth called *cat dirt* or *tow*, having the general character of a bituminous clay;

[a] Saussure, tom. iv. p. 475. [b] Ibid. tom. i. p. 194.

[c] Daubuisson, p. 14 and 133.

but it possesses the singular and dangerous property of heating and actually taking fire some time after exposure to the air. If this cat dirt, instead of being carefully separated and brought up to the surface, be thrown among the waste coal in the pits, the firing of the pit will sometimes take place; and the only remedy may be to drown the works by ceasing to pump out the water. This firing, he adds, which frequently takes place at Dudley, arises from the cause above described: but it is a vulgar error which supposes that the small coals themselves are apt to take fire [d].

CHAP. XXVII.

On the Formation and Character of Turf-banks, or Bogs.

IT is stated, in the Report of the Commissioners appointed by Parliament to investigate the character and extent of the Irish bogs, that more than three-fourths of them are contained within a space bounded on the north by a line drawn across the island from Dublin to Sligo, and on the south by a line drawn from Wicklow Head to Galway; forming a broad belt which widens from east to west. The whole area of the Irish bogs amounts to more than a million acres: in which estimate mere mountain bogs, and even all others which do not

[d] Farey, vol. i. p. 348.

exceed five hundred acres, are omitted[e]. The bogs contained in that part of the above belt which is situated to the east of the river Shannon are collectively called the Bog of Allen; most of which are distinct from each other, and separated by high ridges of dry country[f]. Many of them are contained in basins, the edges of which are abrupt ridges of limestone gravel, and have a substratum of blue clay, incumbent immediately on limestone gravel. The masses of this gravel sometimes exceed three feet in diameter, and have clayey limestone sand interposed between them: sometimes the gravel is stratified in the form of sand-banks, and consists of perfectly rounded shingles, as if formed on a beach[g].

A remarkable instance of a similar bed of shingles, or pebbles, is described in Dr. Hooke's posthumous works in the following terms: "In the Queen's county, Ireland, is a ridge of pebbles called the Ridge of Mary Burrow: it is thirty miles distant from the sea, runs north and south, and is seven miles in length: where highest, it is fourteen or fifteen feet high; but it is very irregular, like as the sands are usually laid on the sea shore. Its sides are very steep: broad enough on the top for four horsemen abreast. It is composed altogether of small rough greyish pebbles, about the size of a man's fist, together with other smaller ones mixed with sand or gravel, but no mixture of clay or loam. None of the adjacent lands have

[e] First Report, p. 4.
[f] Ibid. p. 4.
[g] Second Report, p. 49, 50.

any of the materials of this ridge, but generally there are bogs running up to within a few yards of its foot: and where arable land is near, no mixture of similar pebbles or sand occurs[h]."

It is the opinion of some, that in this boggy part of Ireland extensive forests formerly existed; and that the outer trees of these forests, which were the strongest, being felled, the interior trees were blown down, and formed, in decaying, the origin of bogs. But Mr. Griffith, in his Report on a part of the Bog of Allen, lying in the north-west part of the county of Kildare, denies the probability of the opinion above stated, and gives the following account of the origin of the bogs of that district; which account appears applicable generally. In all the clay lands in this part of the country, wherever water is suffered to remain for any length of time, an incipient formation of bog is the invariable consequence: this formation takes place by the growth of the sphagnum palustre (bog moss) and other aquatic mosses and plants[i]: and of the remains of these plants the mass of the bogs in the above district is composed. He adds, that in some instances, as at Hatfield in Yorkshire, bogs may have been formed by trees falling down and causing an interruption in the flow of waters; but that those which he is describing have accumulated entirely from the growth of mosses in stagnant water; for that in the body of these bogs trees or branches of trees are rarely found, being generally met with only on the edge of the bog[k].

[h] Dr. Hooke's Posthumous Works, p. 438.

[i] First Report, p. 16. [k] Ibid. p. 16.

When the surface of a bog has been drained, the upper and most porous part subsides, the fibres of the moss having lost their watery support, which kept them asunder when alive. The mossy fibres thus collapsing, and being exposed to the atmosphere, become putrid to a certain degree; and then various grasses, and even white clover, will vegetate spontaneously on its surface. But when the *surface* of a bog, in consequence of draining and exposure to the atmosphere, shall have totally lost the texture of the moss, and shall have assumed a close-grained earthy appearance, the bed immediately *beneath* it shall have its mossy fibres so perfect as to render the different species easily distinguishable to the botanist[1]. The average depth of the bogs rarely exceeds thirty feet: the nature of their contents may be understood from the following section of a turf bank (as bogs are often called) in the county of Kildare; which is divided into separate beds, beginning from the uppermost:

	feet
1. A compact bed of a dark reddish-brown colour; not containing any visible fibres of moss	2
2. Of a light reddish-brown colour; containing very perfect fibres of moss	3
3. Of a pale yellowish-brown colour; fibres of moss very perceptible	5
4. Of a deep reddish-brown colour; fibres of moss perceptible	8½
5. Of a blackish-brown colour; fibres of moss scarcely perceptible. This bed contained numerous twigs of birch, alder, and fir; the twigs being hollow . . .	3
6. Of a dull yellowish-brown colour; fibres of moss not visible	3

[1] First Report, p. 63.

7. Compact, and of a blackish-brown colour; fibres not visible 10
8. A black and very compact mass, having a conchoidal fracture; with the lustre and general appearance of *coal* . 4
9. Marl, containing two-thirds of carbonate of lime . . 3
10. Blue clay 4
11. Clay mixed with limestone gravel . . . depth unknown

These beds of turf, or peat, yielded severally from one to two per cent. of ashes, the ashes of the five lowermost being impregnated with oxide of iron; of which substance the ashes of N°. 7. and N°. 8. almost entirely consisted [m].

The upper beds of a bog are often called fibrous and *red* bog; the lower beds, *black* bog: this distinction arising from the difference in *colour* usually perceptible in them. The surface of most of the extensive bogs is of a red colour, and almost entirely composed of fibres of the sphagnum palustre in a very perfect state; and, when very moist, is called *quagmire*. As you descend deeper, the fibrous texture is lost, and the bog becomes compact, and of a black colour. The black bog, both from its compactness and the greater proportion of bitumen contained in it, is most valuable for firing [n]; its compactness is sufficiently accounted for by the pressure of the superincumbent beds: for an account of the increased proportion of bitumen found in it I refer the reader to my Outlines of Mineralogy [o]. The line of distinction between the red and black bog is represented in the Report

[m] First Report, p. 53.
[n] Second Report, p. 48.
[o] Vol. ii. p. 41—44.

to be very easily perceptible; and, as is mentioned in the preceding section, twigs or branches of trees are sometimes found regularly scattered near the junction of the two [p].

The moisture of the bogs seems to depend altogether on the rain water which lodges in their interstices; for it is questionable whether land springs in any instance rise up through the substance of bogs [q]. The cultivation of boggy ground depends partly on draining, partly on paring and burning: the first process removes effectually the superabundant moisture; the last removes the superfluous quantity of vegetable matter, and affords a soil by the residuary ashes. It is found that such trees as have not tap roots (as the birch, alder, and ash) will grow on bog: trees having tap roots will not grow, in consequence of the antiseptic quality of the deeper part of the bog into which those roots penetrate.

There is a very good account of the nature of the Irish bogs, and of their probable and often evident origin, in a paper of the Philosophical Transactions for 1685. It was written by Mr. William King, Fellow of Dublin College, and corresponds very closely, in many points, with the recent Report of the Bog of Allen. It is particularly observed, in the above paper, that the bogs of Ireland are generally higher than the land about them, and therefore that they may easily be drained: and that they are rendered capable of cultivation by cutting and burning, or by even sanding and gra-

[p] Second Report, p. 48. [q] Ibid. p. 10.

velling their surface; so that if a little earth, as when earth is brought to mend the highway, happens to fall on any part of a bog, that part soon acquires a green sod with very fine scutch grass on it[p]. The agriculturists of the present day will perhaps recognize in this scutch grass the so much talked of fiorin of Ireland.

De Luc's account of the formation of bogs agrees with that of the Irish report; but he describes a periodical formation of boggy ground in Holland, and on the south coast of the Baltic, which, alternating with a deposition of alluvion from the rivers of that part of the world, gives rise to a succession of beds very different in their general character from that of a regular turf-bank. He says, that in digging in different parts of Holland the real or continental soil (which in a former part of this volume I have said is called *geest*[q]) is found at different depths: and above this original substratum are found alternate beds of sand and boggy soil, which have been deposited and partly formed by the action of rivers. Thus, an accumulation of bog having taken place by the process already described; and this bog easily slipping forward, unless it has been prevented by artificial means; the rivers subsequently cover the boggy tract with the sand &c. which they bring down; and after a time, bog again accumulating and being again inundated by the rivers, another alternation of sand and bog takes place: and thus, by looking back to a period

[p] Philosophical Transactions, 1685, p. 948—960.

[q] P. 207, lin. 21. supra.

when this part of the country was not inhabited, and these natural processes met consequently with no checks, it is easy to account for the several successive alternations that occur: and it is hence evident that the surface of this part of Europe is constantly, though slowly, advancing towards a higher elevation [q]. It is stated in the Annales du Museum also, that in various parts of Holland the formation of peat or bog goes on very rapidly; and that as these depositions of peat are occasionally buried by the sand brought down by the rivers, on which sand they again form; alternations of peat and sand are found in the sections of that part of Europe [r].

Analogous in their origin at least, if not in the character of their component parts, are the savannahs and swamps so common in America and Asia. Humboldt, in speaking of the Isthmus of Panama, says, that though the pasturage there is at present indifferent, it would be very easy in a country so fertile to form savannahs by levelling the forests [s]. It is stated by Barrow, that all the hills behind the town of Rio Janeiro, the numerous islands in the harbour, and every part of its shores, are covered with forests interspersed with uncultivated plains and tracts of marshy ground; where a constant process of decay, and the reproduction of rank grass and sedges, furnish the materials of unwholesome miasmata [t]. Mr.

[q] De Luc, Lettres, tom. v. p. 330, 335.

[r] Ann. du Mus. tom. ii. p. 91.

[s] Humboldt, tom. i. p. 251.

[t] Barrow's Cochin China, p. 125.

Turner says, that at the feet of the mountains, called by the Bramins Himâloya, which separate Bootan from Bengal, is a wide and extensive plain, covered with woods, and sunk in morasses, and nearly unfit for the support of human life[i]; the exhalations arising from the numerous springs of the adjoining mountains being collected by these impervious woods, and producing a most fatal atmosphere[k].

From a review of all that has been said it is evident, that the formation of bogs or swamps of every kind depends on the retention of stagnant moisture in the first instance; and on the consequent vegetation of mosses and other aquatic plants: and it follows from hence, that wherever the natural substratum is impervious to water, there (whether in an elevated or low situation, whether on granite or on clay) moors may be formed: and thus bogs are commonly met with among the granitic summits of Dartmoor: and De Luc describes a turf-bed twelve feet thick on the top of the Blockberg, which is of compact granite, and one of the highest summits of the Hartz[l].

In some instances various instruments of art have been found at considerable depths below the surface of a bog. Thus in 1786, a woollen coat was found seventeen feet beneath the surface of a bog in Westmeath; where were also found a razor with a wooden handle, some iron heads of arrows,

[i] Turner's Tibet, Introduction, p. vii.

[k] Ibid. p. 21.

[l] De Luc, Lettres, tom. iii. p. 266.

and large wooden bowls, (some of which were only half made,) with the remains of turning tools; firkins also of butter, and brass vessels [m]. Such facts, as that just stated, may be reasonably accounted for on the supposition that large tracts of bog have slipped down from their original level, and have advanced to a considerable distance from the spot they originally occupied: and such subsidences are said by De Luc to happen not unfrequently. Supposing therefore such an accident to have happened in the case of the bog of Westmeath, and that some peasant, whose occupation was that of a carpenter, had his hut near the edge of the bog; it is highly probable, that, intent on escaping from the threatening evil, he would hastily quit his hut with as few incumbrances as possible, and that his household stores and tools would be overwhelmed by, and buried in, the bog. It is the opinion of De Luc, that the submerged forests in the isle of Axholme and other parts of Lincolnshire, owe their origin to similar descents of the ground on which they grew. Such a change of place is related in the Philosophical Transactions to have happened to Solway Moss in the year 1771. This Moss, which is situated between the rivers Sark and Esk, on the east side of the road leading from Moffat to Carlisle, was of the quag kind; a sort of moss covered superficially with a turf of heath and coarse aquatic grasses, the lower part having scarcely more consistence than mud. In the night of December 16, 1771, this moss broke through

[m] Second Report, p. 174.

its usual barrier, and overflowed 400 acres to the south-eastward[n].

Although it is stated, with respect to the Bog of Allen, that trees or branches of trees are rarely found in the body of the bogs, but only at their edges; yet it is known that in many parts of Ireland, and in various other parts of the world, bog timber occurs in great abundance. Thus Mr. Farey says, that many peat bogs not now in progress of formation, on some of the gritstone heights of Derbyshire, contain trees that once grew on them: and he adds, that the mosses of this peat resemble those of the Irish bogs[o]. In the Philosophical Transactions for 1669, in a description there given of the bogs of Cheshire, the writer says, "In Cheshire, which is called the Vale Royal of England, are tracts of ground called mosses, a kind of moorish boggy ground. These mosses, which are exceedingly frequent, serve for turf; being cut out into pieces like brick, and then dried in the sun. In these mosses is found much *fir* wood, in a fossile state, which serves the country people sometimes even for small timber uses, but very commonly for fuel, and for *candles*[p]." So again, the fossile fir wood of Ireland is very commonly used as a substitute for candles; for which purpose it is split into thin laths, and formed by the knife to the proper shape: so that, with merely the difference of the *fossile* and the *recent* pine, the Irish

[n] Philosophical Transactions, 1772, p. 124.

[o] Farey, vol. i. p. 311, 312.

[p] Philosophical Transactions, 1669, p. 1061.

rustic is often perhaps employed during the winter season like his predecessor in Virgil,

——ferroque faces inspicat acuto.

With the subject of the present chapter, I close the investigation of the changes produced on the surface of the earth by the operation of existing causes; to which I shall only subjoin a few concluding remarks.

CONCLUSION.

In the former part of this volume I have attempted to shew, by a description of the requisite phenomena, that the evidence in support of a consistent theory of the earth, deducible from its general structure, is both of an imperfect and equivocal character. And a very slight review of the changes produced on the surface of the strata by the operation of existing causes will shew, that these are entirely inadequate to the explanation of the origin of the strata themselves.

The action of rivers for instance, and of the sea, and of the wind, produces nothing but accumulations of mere sand: and though it may be said that many of the natural strata are nothing more than aggregated particles of sand; yet, without insisting on the internal evidence of their chemical origin in many instances, such strata are constantly alternating with, or passing into, large-grained conglomerates, and even into crystallized rocks. Again, the action of glaciers and the deposition of cal-

careous tufa are far too limited to account for extensive formations; and it has been shewn that coral reefs do not answer to coralline calcareous strata: neither do the productions of volcanoes correspond with the character of the most analogous strata: and even in peat, though itself often closely resembles coal, the characteristic alternation of gritstones, &c. is entirely wanting. Having then endeavoured to shew the numerous difficulties which occur in attempting to explain the phenomena of geology from the internal evidence afforded by the strata themselves, or from the analogy of the effects produced by actually existing causes; I shall conclude this volume with some short reflections which have been suggested by the foregoing investigation.

Considering then, of how very small a portion even of the earth's surface we have at present any thing like an accurate knowledge; and recollecting the peculiar difficulties of this branch of natural science, arising from the infinite variety in the characters of minerals; (in consequence of which Saussure has been led to observe, that nature, if in any, has not in this department distributed individuals into *classes* and *genera*[q];) considering also, that whoever has long accustomed himself to geological observations, will easily recollect that at different periods he has viewed the same phenomena with very different eyes; and that the history of geology shews the same thing to have happened to the most acute and accurate ob-

[q] Saussure, tom. i. p. 99.

servers; that it often also happens that different persons are impressed differently at the same moment by the same phenomena; and lastly, that it is certain from the numerous and remarkably dissimilar systems of different philosophers, that nothing like probability of any high order has been yet attained in geological reasoning; from all these considerations we may at least be convinced, that the science of geology is at present so completely in its infancy as to render hopeless any attempt at successful generalization, and may therefore be induced to persevere with patience in the accumulation of useful facts.

THE END.

ERRATA.

Pag. 18, note [d], *for* "p. 120 &c." *read* "p. 140 &c."
27, last line, *for* "Mitchell" *read* "Holloway."
34, [u], *for* "vii. 98." *read* "vii. 94."
41, line 16, *dele the words* "who observes that," *and put a full stop after the preceding word.*
64, note [f], *for* "p. 273, 274." *read* "p. 280, 282."
65, [i], *for* "p. 88." *read* "p. 141 and 89."
65, [k] and [l], *transpose the references of* [k] and [l].
70, [i], *for* "p. 112." *read* "p. 100."
72, [l], *for* "De Luc's, vol. v. p. 309." *read* "De Luc's Travels, vol. v. p. 369."
77, [d], *incorrect reference.*
97, [y], *after* "Jameson, vol. iii. p. 152." *add* "and De Luc, Lettres, tom. iv. p. 557—568."
99, [i], *for* "vol. iii." *read* "vol. ii."
107, line 4, *for* "no" *read* "few."
107, note [s], *for* "p. 55, and tom. ii. p. 126." *read* "p. 54."
118, [c], *for* "vol. ii." *read* "vol. iii."
147, [z], *for* "p. 17 and 99." *read* "p. 14."
149, [g], *incorrect reference.*
154, line 8, *omit the words* "according to Mr. Murray."
154, note [i], *for* "Murray's Comparative View," *read* "Comparative View."
157, [u], *for* "p. 265." *read* "p. 265 and 424."
159, [a], *incorrect reference.*
161, [f], *for* "Ann. du Mus." *read* "Essai de Cuv. et Brongn."
162, [i], *for* "Ann. du Mus. tom. xi. p. 57, 237, and 326." *read* "Essai de Cuv. and Brongn. p. 57, 58."
173, [i], *for* "De Luc, Lettres, tom. i." *read* "De Luc's Travels, vol. i."
173, [l], *for* "Ibid. p. 492." *read* "Ibid. vol. i. p. 61."
188, [n], *for* "p. 329." *read* "p. 354."
197, [p], *for* "p. 91." *read* "p. 9."
204, [h], *for* "p. 459." *read* "p. 228."
206, [m], *for* "p. 228 or 459." *read* "p. 459."
210, [t], *incorrect reference.*
221, [s], *for* "vol. i." *read* "vol. ii."
226, line 24—26. *Dele from* "consisting" *to* "preservation."
231, note [r], *for* "p. 122." *read* "p. 222."
233, [y], *for* "p. 288." *read* "p. 188."